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Preparation and Certification of Large-Sized Dried (LSD) Spike IRMM-1027o

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Summary

IRMM Large-Sized Dried (LSD) Spikes are widely used as a fundamental part of the fissile material control of irradiated nuclear fuel and have been provided on a regular basis to safeguards authorities and industry for more than 10 years. This report describes the preparation and certification of a new batch of LSD Spikes. IRMM-1027o is a dried nitrate material in cellulose acetate butyrate (CAB), certified for the mass of uranium and plutonium and isotope amount ratios per unit. The material was produced following ISO Guide 34:2009 [1].

The certified reference materials uranium metal EC NRM 101, enriched uranium metal NBL CRM-116 and plutonium metal CETAMA MP2 were used as starting materials to prepare the mother solution. This solution was dispensed by means of an automated robot system into individual units and dried down. A solution of an organic substance, cellulose acetate butyrate (CAB), was dried on the spike material as a stabilizer to retain the dried material at the bottom of the vial.

Between unit-homogeneity was quantified and stability during dispatch and storage were assessed in accordance with ISO Guide 35:2006 [2].

The certified values were obtained from the gravimetric preparation of the mother solution, taking into account the mass, purity and isotopic abundances of the starting materials, the mass of the mother solution, and the mass of an aliquot in each individual unit. The certified values were confirmed by isotope dilution thermal ionisation mass spectrometry (ID-TIMS) and thermal ionisation mass spectrometry (TIMS) as independent confirmation methods.

Uncertainties of the certified values were estimated in compliance with the Guide to the Expression of Uncertainty in Measurement (GUM) [3] and include uncertainties related to possible inhomogeneity and to characterisation.

This spike CRM is applied as a calibrant to measure the uranium and plutonium amount content of dissolved spent nuclear fuel solutions using isotope dilution mass spectrometry (IDMS). Each unit contains about 50 mg of uranium with a relative mass fraction $m(^{235}U)/m(U)$ of 19.3% and 1.8 mg of plutonium with a relative mass fraction $m(^{239}Pu)/m(Pu)$ of 97.8% as dried nitrate in CAB. The whole amount of sample per unit has to be used for analysis.

The following values were assigned:

	Isotope amount ratios	
	Certified value [1)] [mol/mol]	Uncertainty [2)] [mol/mol]
$n(^{234}U)/n(^{238}U)$	0.0025682	0.0000007
$n(^{235}U)/n(^{238}U)$	0.24239	0.00005
$n(^{240}Pu)/n(^{239}Pu)$	0.022422	0.000006
$n(^{241}Pu)/n(^{239}Pu)$	0.0001793	0.0000024
$n(^{242}Pu)/n(^{239}Pu)$	0.0000757	0.0000008
The certified masses and the uncertainties of ^{235}U, ^{238}U and ^{239}Pu per unit are listed in Annex 1.		

[1)] The certified values are traceable to the values on the respective metal certificates (Annexes 2-6). The reference date for the plutonium and uranium isotope amount ratios is November 1, 2012.

[2)] The certified uncertainty is the expanded uncertainty with a coverage factor $k = 2$ corresponding to a level of confidence of about 95 % estimated in accordance with ISO/IEC Guide 98-3, Guide to the Expression of Uncertainty in Measurement (GUM:1995), ISO, 2008.

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Glossary

ANOVA	Analysis of variance
BIPM	Bureau International des Poids et Mesures (International Bureau of Weights and Measures)
c	amount of substance concentration
CAB	Cellulose acetate butyrate
CI	confidence interval
CRM	Certified reference material
EC	European Commission
ESARDA	European Safeguards Research and Development Association
GUM	Guide to the Expression of Uncertainty in Measurements [3]
IAEA	International Atomic Energy Agency
IDMS	Isotope dilution mass spectrometry
ID-TIMS	Isotope dilution thermal ionisation mass spectrometry
IRMM	Institute for Reference Materials and Measurements of the JRC
ITU	Institute for Transuranium Elements of the JRC
ITVs	International Target Values
JRC	Joint Research Centre of the European Commission
k	Coverage factor
LSD	Large-Sized Dried
M	Molar mass
MS	Mass spectrometry
$MS_{between}$	Mean of squares between-unit from an ANOVA
SDS	Safety data sheet
MS_{within}	Mean of squares within-unit from an ANOVA
n	Number of replicates per unit
N	Number of samples (units) analysed
rel	Index denoting relative figures (uncertainties etc.)
RM	Reference material
RSD	Relative standard deviation
RSE	Relative standard error (=RSD/$\sqrt{n}$)
r^2	Coefficient of determination of the linear regression
s	Standard deviation
s_{bb}	Between-unit standard deviation; an additional index "rel" is added when appropriate

$s_{between}$	Standard deviation between groups as obtained from ANOVA; an additional index "rel" is added as appropriate
SE	Standard error
SI	International System of Units
s_{meas}	Standard deviation of measurement data; an additional index "rel" is added as appropriate
s_{within}	Standard deviation within groups as obtained from ANOVA; an additional index "rel" is added as appropriate
s_{wb}	Within-unit standard deviation
TIMS	Thermal Ionisation Mass Spectrometry
u	Standard uncertainty
U	Expanded uncertainty
u^*_{bb}	Standard uncertainty related to a maximum between-unit inhomogeneity that could be hidden by method repeatability; an additional index "rel" is added as appropriate
u_{bb}	Standard uncertainty related to a possible between-unit inhomogeneity; an additional index "rel" is added as appropriate
u_c	Combined standard uncertainty; an additional index "rel" is added as appropriate
u_{cal}	Standard uncertainty of calibration
u_{char}	Standard uncertainty of the material characterisation; an additional index "rel" is added as appropriate
u_{CRM}	Combined standard uncertainty of the certified value; an additional index "rel" is added as appropriate
U_{CRM}	Expanded uncertainty of the certified value; an additional index "rel" is added as appropriate
u_{lts}	Standard uncertainty of the long-term stability; an additional index "rel" is added as appropriate
u_{meas}	Standard measurement uncertainty
U_{meas}	Expanded measurement uncertainty
u_{sts}	Standard uncertainty of the short-term stability; an additional index "rel" is added as appropriate
$\bar{y}$	Arithmetic mean
α	Significance level
$\nu_{MSwithin}$	Degrees of freedom of MS_{within}

1 Introduction

1.1 Background

The International Target Values for Measurement Uncertainties in Safeguarding Nuclear Materials (ITVs) are uncertainties to be considered in judging the reliability of analytical techniques applied to industrial nuclear and fissile material, which are subject to safeguards verification. ITVs should be achievable under the conditions normally encountered in typical industrial laboratories or during actual safeguards inspections. In 2010 the International Atomic Energy Agency (IAEA) together with the European Safeguards Research and Development Association (ESARDA), international standardisation organisations and regional safeguards authorities published a revised version of the ITVs. The ITVs-2010 are intended to be used by nuclear plant operators and safeguards organizations as a reference of the quality of measurements necessary for nuclear material accountancy [4]. The series of IRMM-1027 Large-Sized Dried (LSD) spikes are prepared by IRMM to meet the existing requirement for reliable isotope reference materials for the accountancy measurements of uranium and plutonium by IDMS in compliance with the ITVs-2010 in spent nuclear fuel. These spikes contain relatively large amounts of uranium and plutonium (50 mg U and 1.8 mg Pu), isotopically different to the uranium and plutonium in the sample and are in dried nitrate form. About 1200 units of IRMM-1027 LSD spikes are prepared annually to fulfil the demands for fissile material control from European Safeguards Authorities and industry [5].

1.2 Choice of the material

The IRMM-1027o batch of LSD spikes was prepared from certified reference metals (EC NRM 101, NBL CRM-116 and CETAMA MP2). Each unit contains about 50 mg of uranium with a relative mass fraction $m(^{235}U)/m(U)$ of 19.3% and 1.8 mg of plutonium with a relative mass fraction $m(^{239}Pu)/m(Pu)$ of 97.8%. The relative mass fraction $m(^{235}U)/m(U)$ is below 20%, so that for accountability purposes the uranium is classified as "low enriched". Individual units are certified for the mass of plutonium and uranium and for the isotope amount ratios. The uranium and plutonium amount content in a single IRMM-1027 LSD spike is such that no dilution of a typical sample of dissolved fuel is needed before measurement by IDMS. As the dried nitrates could flake off the vial surface over time or during transport, an organic polymer in the form of cellulose acetate butyrate (CAB) is added to retain the material at the bottom of the vial.

1.3 Design of the project

The individual units of IRMM-1027o LSD spikes were prepared by dispensing aliquots of the mother solution into vials and dried down. This solution was prepared gravimetrically by dissolving uranium and plutonium certified reference metals in nitric acid. Finally, the dried nitrate was treated with CAB for preservation during storage and transport. The certified masses and the isotope amount ratios are based on the data given by the weighing certificates and the certificate of the starting materials. Confirmation measurements, homogeneity and stability assessment were combined using IDMS analysis on selected vials.

2 Participants

Project management and evaluation, processing, homogeneity study, stability study and characterisation have been performed at the European Commission, Joint Research Centre, Institute for Reference Materials and Measurements (IRMM), Geel, Belgium.

3 Material processing and process control

3.1 Origin and purity of the starting materials

For the preparation of the IRMM-1027o LSD spikes, CRMs of high purity uranium (EC NRM 101, Geel, Belgium and NBL CRM-116, Argonne, USA) and plutonium (CETAMA MP2, Marcoule, France) metals were used as starting materials. The isotopic composition and the purity of the metals are given in Annexes 2-6.

3.2 Processing

The respective units of plutonium MP2 metal for the preparation of the IRMM-1027o mother solution were weighed and transferred into a pre-cleaned 3 L borosilicate flask. The metal was dissolved by addition of a solution prepared from concentrated nitric acid (*p.a.*, Merck, Darmstadt, Germany), a few drops of concentrated hydrofluoric acid (*p.a.*, Merck, Darmstadt, Germany) and deionised water. After heating on a hot plate at 90 ^{o}C for several days, the addition of a solution and the heating step were repeated until the plutonium metal dissolved completely. The dissolution of plutonium metal was controlled by visual inspection. Subsequently the respective units of enriched uranium metal (NBL CRM-116) and of natural uranium metal (EC NRM 101) were weighed and added into the above solution. Prior to weighing, the units of NBL CRM-116 metal were etched with 1 M HNO_3 to remove surface oxides, and subsequently rinsed with deionised water and acetone (*p.a.*, Merck, Darmstadt, Germany) and dried down. Finally, concentrated nitric acid and deionised water were added to adjust the concentration of the solution to 5 M HNO_3. The solution was left to homogenise for a few days with occasionally swirling by hand, and weighed to determine the final concentrations of the uranium and plutonium in the solution, taking into account the necessary corrections for air buoyancy effects.

Prior to dispensing the mother solution into individual vials (see section 3.3), four aliquots were analysed by ID-TIMS to confirm the concentration of plutonium and uranium and one aliquot by TIMS to confirm the isotope amount ratios from gravimetric preparation.

Dispensing and weighing of the solution into individual vials were performed by a validated automated system, which was installed at IRMM in collaboration with Nucomat (Lokeren, Belgium) [6]. The major components of the system are a robot, two balances and a dispenser. The robot is software driven and designed to control all movements inside the glove box, such as identifying the vial with a barcode reader, dispensing and weighing of an aliquot of the solution (2.5 g) into the vials. The weighing component is equipped with a semi-analytical balance (Sartorius TE124S, Göttingen, Germany) and a 5 kg balance (Sartorius TE6101, Göttingen, Germany) to monitor the mass of the mother solution during dispensing and to correct for possible evaporation losses. The whole solution (about 3 kg) was dispensed into 1215 units in five consecutive working days.

The drying of the dispensed solution contained in the units was carried out on a hot plate equipped with a sensor for controlling the surface temperature. This temperature was increased to a maximum of 60 ^{o}C and the units were kept at this temperature for several days (typically 4-5 days continuous heating) to evaporate the solution completely. After the solution had dried, about 0.7 mL of 10 wt% CAB solution in acetone (35-39 wt% butyryl content, Acros, New Jersey, USA) was added. This solution was evaporated at room temperature and then heated to about 45 ^{o}C to dry completely. CAB was added to retain the dried material at the bottom of the vial so that it can resist physical shocks that might be encountered during transport and to avoid flaking-off during long-term storage. This cellulose

matrix dissolves readily in warm nitric acid solution and has no significant effect on the subsequent IDMS analysis. Two separate glove boxes were used for drying and CAB application, allowing the preparation of up to 48 units per week. The vials were closed with an iso-versilic stopper and an aluminium cap, sealed in PVC package and labelled. The processing steps are shown in Figure 1.

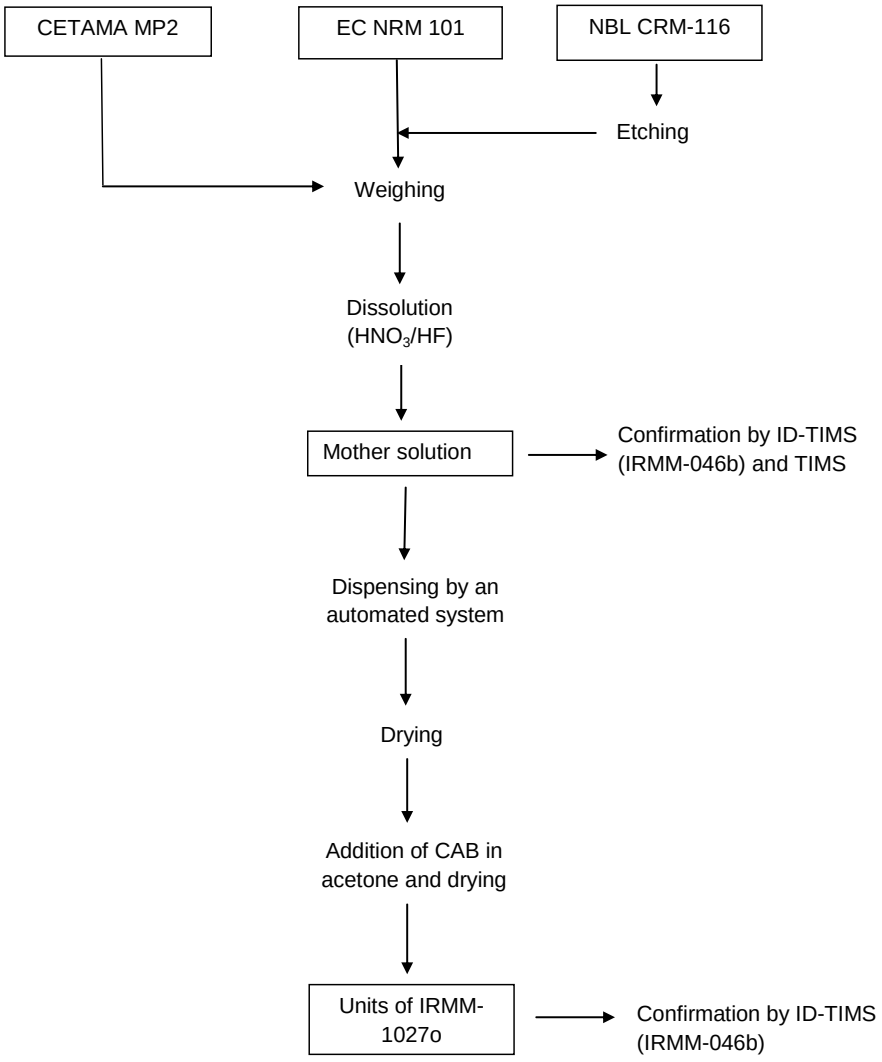

Fig. 1 Preparation of IRMM-1027o LSD spikes

3.3 Process control

This section describes the confirmation measurements performed on the mother solution prior to dispensing into individual vials.

Four aliquots (about 2.5 g each) were individually spiked with a mixed U/Pu spike CRM (IRMM-046b) for ID-TIMS analysis to confirm the concentration of uranium and plutonium in the solution from gravimetric preparation. The IRMM-046b certificate can be found in Annex 8. One un-spiked aliquot was analysed to determine the isotopic composition (e.g. uranium and plutonium amount ratios) by thermal ionisation mass spectrometry (TIMS).

The spiked and un-spiked solutions were evaporated to dryness and dissolved in 200 μL nitric acid (c = 2 mol L^{-1}, *p.a.*, Merck, Darmstadt, Germany). To achieve isotopic equilibrium between the spike and the sample, first 50 μL iron(II) chloride solution (c = 1.25 mol L^{-1}, *p.a.*, Merck, Darmstadt, Germany) was added to reduce plutonium to Pu(III) and then 100 μL hydroxyl ammonium chloride solution (c = 1 mol L^{-1}, *p.a.*, Merck, Darmstadt, Germany) and 100 μL sodium nitrite (c = 1 mol L^{-1}, *p.a.*, Merck, Darmstadt, Germany) to oxidise Pu(III) to Pu(IV). Finally 430 μL concentrated nitric acid were added to obtain Pu(IV) in nitric acid with an amount of substance concentration of 8 mol L^{-1}. The U/Pu separation was performed using anion-exchange columns (Bio-Rad AG1-X4, 100-200 mesh, Bio-Rad, Hercules, USA). Uranium was eluted with nitric acid (c = 8 mol L^{-1}) and plutonium with nitric acid (c = 0.35 mol L^{-1}). The separation was repeated once for uranium and twice for plutonium to avoid isobaric interference in the TIMS measurement. Both purified fractions were evaporated and re-dissolved in nitric acid (c = 1 mol L^{-1}) to give concentrations of 1 mg Pu mL^{-1} and 5 mg U mL^{-1} for loading the rhenium filaments.

The isotopic measurements of the uranium and plutonium were performed on a Triton TIMS (Thermo Fischer Scientific, Bremen, Germany). The mass spectrometer was calibrated with IRMM-074/10 uranium and IRMM-290/A3 plutonium isotopic reference solutions to correct for mass fractionation effects. The uncertainty of the $n(^{242}Pu)/n(^{239}Pu)$ ratio from IRMM-290/A3 is very small and therefore has a minor contribution to the total uncertainty budget of the reference measurements of Pu MP2 in 2007 (Annex 4) and to the current confirmation measurements of IRMM-1027o by IDMS. Therefore, the uncertainty of the IRMM-290/A3 standard does not add a significant uncertainty contribution when comparing the gravimetrical and measured values (ID-TIMS) in IRMM-1027o. The results of the confirmation measurements are shown in Annex 9 and Annex 10.

A significant difference between the measured (TIMS) and gravimetric value was observed for the $n(^{238}Pu)/n(^{239}Pu)$ ratio. This is due to an isobaric interference with ^{238}U in the Pu fraction during isotope ratios measurement, coming from an incomplete removal of uranium in the plutonium fraction. A small difference was also observed for the $n(^{236}U)/n(^{238}U)$ ratio. However, these differences do not influence the calculation of the ^{239}Pu, ^{235}U and ^{238}U amount contents as the $n(^{238}Pu)/n(^{239}Pu)$ and $n(^{236}U)/n(^{238}U)$ ratios are not the input parameters of the simplified IDMS equation. For all other plutonium and uranium amount ratios the agreement between measured and gravimetric values was achieved. For the above reasons the $n(^{238}Pu)/n(^{239}Pu)$ and $n(^{236}U)/n(^{238}U)$ ratios are given only as an additional information in the certification report.

A unit of IRMM-1027o LSD spike can be seen in Figure 2.

Fig. 2 Unit of IRMM-1027o LSD spike

4 Homogeneity

A key requirement for any reference material is the equivalence between the various units. In this respect, it is relevant whether the variation between units is significant compared to the uncertainty of the certified value. In contrast to that it is not relevant if this variation between units is significant compared to the analytical variation. Consequently, ISO Guide 34 requires RM producers to quantify the between unit variation. This aspect is covered in between-unit homogeneity studies. The homogeneity study was combined together with the measurements to confirm the gravimetric preparation of the IRMM-1027o LSD spikes.

4.1 Between-unit homogeneity

The between-unit homogeneity was evaluated to ensure that the certified values of the CRM are valid for all 1215 units of the material, within the stated uncertainty.

The number of selected units corresponds to approximately the cubic root of the total number of the produced units (1215). Twelve units were selected using a random stratified sampling scheme covering the whole batch for the between-unit homogeneity test. The batch was divided into twelve groups (with a similar number of units) and one unit was selected randomly from each group. The whole amount of sample per unit (equals minimum sample intake) was taken, chemically separated and the isotopic measurements were performed on a fraction of the purified sample. Each sample was measured in four replicates together with the isotopic standards to correct for instrumental mass fractionation. This enabled four independent samples to be measured on the same TIMS sample carrousel on the same day. Therefore, the measurements for all twelve units of IRMM-1027o were performed under intermediate precision rather than repeatability conditions. The respective fractions of the samples were measured in a randomised manner to be able to separate a potential analytical drift from a trend in the filling sequence. Some of the data had to be excluded from the evaluation due to technical reasons, such as e.g. loss of sample prior to total evaporation measurement, high background from the filament due to unusually high filament temperatures, very low signal intensity. The results are shown as graphs in Annex 11.

Regression analyses were performed to evaluate potential trends in the analytical sequence as well as trends in the filling sequence. No trends in the filling sequence or the analytical sequence were visible.

Quantification of between-unit inhomogeneity was accomplished by analysis of variance (ANOVA), which can separate the between-unit variation (s_{bb}) from the within-unit variation (s_{wb}). The latter is equivalent to the method repeatability if the individual samples are representative for the whole unit.

Evaluation by ANOVA requires unit means that follow at least a unimodal distribution and results for each unit that follow unimodal distributions with approximately the same standard deviations. Distribution of the unit means was visually tested using histograms and normal probability plots. Minor deviations from unimodality of the individual values do not significantly affect the estimate of between-unit standard deviations. The results of all statistical evaluations are given in Table 1.

Table 1: Results of the statistical evaluation of the homogeneity studies at 99 % confidence level

Amount content (IDMS)	Trends		Outliers		Distribution	
	Analytical sequence	Filling sequence	Individual results	Unit means	Individual results	Unit means
^{235}U	no	no	none	none	normal	normal
^{238}U	no	no	none	none	normal	normal
^{239}Pu	no	no	none	none	normal	normal

One has to bear in mind that $s_{bb,rel}$ and $s_{wb,rel}$ are estimates of the true standard deviations and therefore subject to random fluctuations. Therefore, the mean square between groups ($MS_{between}$) can be smaller than the mean squares within groups (MS_{within}), resulting in negative arguments under the square root used for the estimation of the between-unit variation, whereas the true variation cannot be lower than zero. In this case, u^*_{bb}, the maximum inhomogeneity that could be hidden by method repeatability, was calculated as described by Linsinger *et al.* [7]. u^*_{bb} is comparable to the limit of detection of an analytical method, yielding the maximum inhomogeneity that might be undetected by the given study setup.

Method repeatability ($s_{wb,rel}$), between–unit standard deviation ($s_{bb,rel}$) and $u^*_{bb,rel}$ were calculated as:

$$s_{wb,rel} = \frac{\sqrt{MS_{within}}}{\bar{y}} \qquad \textbf{Equation 1}$$

$$s_{bb,rel} = \frac{\sqrt{\frac{MS_{between} - MS_{within}}{n}}}{\bar{y}} \qquad \textbf{Equation 2}$$

$$u^*_{bb,rel} = \frac{\sqrt{\frac{MS_{within}}{n}\sqrt[4]{\frac{2}{v_{MSwithin}}}}}{\bar{y}} \qquad \textbf{Equation 3}$$

MS_{within} mean square within a unit from an ANOVA

$MS_{between}$ mean squares between-unit from an ANOVA

$\bar{y}$ mean of all results of the homogeneity study

n mean number of replicates per unit

$v_{MSwithin}$ degrees of freedom of MS_{within}

The uncertainty contribution for homogeneity was determined by method intermediate precision because the isotopic measurements for all selected units of IRMM-1027o could not be carried out on the same day. Consequently, day-to-day effects can occur that could mask the between-unit variation. Therefore, the data were first checked using one way-ANOVA for any significant difference in between-day means. A significant difference was observed for ^{239}Pu and ^{238}U data. For that reason, the data were first divided by the respective day mean and the resulting data were evaluated using one way-ANOVA. The results of the evaluation

of the between-unit variation are summarised in Table 2. The resulting values from the above equations were converted into relative uncertainties.

Table 2: Results of the homogeneity studies

Amount content (IDMS)	$s_{wb,rel}$ [%]	$s_{bb,rel}$ [%]	$u^*_{bb,rel}$ [%]
^{235}U	0.0136	0.0174	0.0034
^{238}U	0.0329	0.0259	0.0081
^{239}Pu	0.0167	0.0107	0.0044

The homogeneity study showed no outlying unit means and no trends in the filling sequence. Therefore, the between-unit standard deviation can be used as estimate of u_{bb}. As u^*_{bb} sets the limits of the study to detect inhomogeneity, the larger value of s_{bb} and u^*_{bb} is adopted as uncertainty contribution to account for potential inhomogeneity.

4.2 Within-unit homogeneity and minimum sample intake

The within-unit inhomogeneity does not influence the uncertainty of the certified value when the minimum sample intake is respected, but determines the minimum size of an aliquot that is representative for the whole unit. Sample sizes equal to or above the minimum sample intake guarantee the certified value within its stated uncertainty. The uranium and plutonium amount content in a single IRMM-1027 LSD spike is such that no dilution of a typical sample of dissolved fuel is needed. The only quantitative step needed at the reprocessing plant laboratory is to weigh as accurately as possible an aliquot of the dissolved fuel solution onto the spike and ensure complete mixing of spike and sample. The whole amount of sample per unit has to be used for analysis and thus equals the minimum sample intake. Quantification of within-unit inhomogeneity to determine the minimum sample intake for IRMM-1027o is therefore not necessary.

5 Stability

Stability testing is necessary to establish conditions for storage (long-term stability) as well as conditions for dispatch to the customers (short-term stability). The IRMM-1027o is a mixed U/Pu reference material, consisting of U and Pu radionuclides. Therefore, the certified isotope amount ratios and amount contents of this reference material are unstable by nature following the law of radioactive decay, depending on the respective half-lives [8, 9]. The IRMM-1027o certificate states the reference date for the certified values under "Description of the material". This is the exact date to which the certified values are referred to.

Temperatures up to 40 °C could be reached for regular shipment of reference materials. Therefore, stability under these conditions had to be demonstrated. The shipment of nuclear material follows the legal requirements related to radioprotection measures for transport of radioactive materials. The packing of radioactive material is formally divided into two phases, the packing of the inner package and the packing of the container according to regulations and respective procedures [10]. IRMM-1027o LSD spikes are sealed in plastic bags, put in a plastic Type A container for radioactive materials and are transported finally in large sealed containers. From the package material specification and the fact that the transport of radioactive material does not take longer than one week, the IRMM-1027o units packed as described above are never exposed to temperatures outside the range of 4 to 40 ^{o}C.

Taking into account that

1) Certified values of IRMM-1027o are valid for a specific reference date given on the certificate only;
2) The dried uranyl and plutonium nitrates are embedded in an organic substance providing a stable layer at the bottom of the vial to preserve the integrity during transport;
3) Preparation time of a batch of the IRMM-1027 series from dispensing of the mother solution until confirmation measurements on the completed LSD spikes in CAB takes about 6-10 months;
4) The packing of IRMM-1027o is such that the units are never exposed to temperatures outside the range of 4 to 40 ^{o}C;
5) Transport of IRMM-1027o does not exceed one week;
6) IRMM has provided IRMM-1027 series of LSD spikes for more than 10 years to customers

the short-term and long-term stability for IRMM-1027o are demonstrated in combination with confirmation measurements of the gravimetrically certified values and from experience in preparing the same kind of reference material over years, as described in the following sections 5.1 and 5.2.

5.1 Short-term stability study

From more than 10 years of experience in preparing and certifying IRMM-1027 series of LSD spikes, the nature of the certified values and the stringent constraints for packaging and transport of radioactive materials (see also section 5), the short-term 'stability' of the certified properties during transport is guaranteed. Short-term stability of the CAB applied to IRMM-1027o was demonstrated using a modified isochronous design [11]. In that approach, samples are stored for a certain time at different temperature conditions. Afterwards, the samples are moved to conditions where further degradation can be assumed to be negligible (reference conditions). At the end of the isochronous storage, the samples are analysed simultaneously under repeatability conditions. To assess the short-term stability of the CAB with 35-39 wt% butyryl content used in the preparation of IRMM-1027o, samples were stored at 4 °C and 40 °C for one week at each temperature. The reference temperature was set to 18 °C (see also section 5). The test samples contained only CAB with 35-39 wt% butyryl content without plutonium and uranyl nitrate. The same vials and the same CAB preparation procedure were used for IRMM-1027o. Eight units were prepared for each temperature (24 units in total). The samples could not be analysed by direct measurements to assess deterioration. Therefore a visual observation was made before and at the end of the study. No visual difference in the appearance of the CAB layers (hair cracks or flaking-off) was observed before and after the test. Table 3 gives details on the visual inspection per respective test temperature and unit.

Table 3: Results of the CAB short-term stability study

Vial No	Observation before	Observation after
	+4 °C	
1211	bubbles, not adhering well at the edges of the bottom of the vial	no flaking or cracking
1213	not adhering well at the edges of the bottom of the vial	no flaking or cracking
1215	bubbles, not adhering well at the edges of the bottom of the vial	no flaking or cracking
1220	bubbles, not adhering well at the edges of the bottom of the vial	no flaking or cracking
1222	long bubbles at the edge, small bubbles on the wall	no flaking or cracking
1226	long bubbles at the edge, small bubbles on the wall	no flaking or cracking
1230	adheres	no flaking or cracking
1232	adheres	no flaking or cracking
	+18 °C	
1214	long bubbles at the edge, small bubble(s) on the wall	no flaking or cracking
1217	small bubble(s) on the wall	no flaking or cracking
1221	long bubbles at the edge, small bubble(s) on the wall	no flaking or cracking
1223	small bubble(s) on the wall	no flaking or cracking
1224	adheres	no flaking or cracking
1227	adheres	no flaking or cracking
1229	adheres	no flaking or cracking
1234	small bubble(s) on the wall	no flaking or cracking
	+40 °C	
1212	small bubble(s) on the wall	no flaking or cracking
1216	small bubble(s) on the wall	no flaking or cracking
1218	adheres	no flaking or cracking
1219	long bubbles at the edge, small bubble(s) on the wall	no flaking or cracking
1225	small bubble(s) on the wall	no flaking or cracking
1228	long bubble at the edge	no flaking or cracking
1231	adheres	no flaking or cracking
1233	bubbles at the edge	no flaking or cracking

The short-term stability study demonstrated that IRMM-1027o LSD spikes show no sign of deterioration during transport period and can be shipped to customers.

5.2 Long-term stability study

The long-term stability for IRMM-1027o is demonstrated in combination with confirmation measurements of the gravimetrically certified values and in addition underpinned by measurement results carried out using IRMM-1027m LSD spikes over a period of 4 years [12]. The applied approach for IRMM-1027o of combining confirmation and homogeneity IDMS measurements (see Annex 11 and Annex 12) already demonstrated the stability for the IRMM-1027 LSD series from the time of starting the dispensing until the time of performing confirmation measurements on randomly selected units. This time span is for each of the LSD batches about 6-10 months. Furthermore, long-term stability of the certified

properties of IRMM-1027o is underpinned by confirmation measurements from previous IRMM-1027 batches, which have the same characteristics as IRMM-1027o. Particularly, the compatibility study carried out using IRMM-1027m proves the long-term stability of the IRMM-1027 series LSD spikes. After preparation and certification of IRMM-1027m during 2008-2009, spikes from this batch have been used until to date for an inter-calibration campaign inter-linking selected plutonium reference materials on a metrological basis applying state-of-the-art measurement procedures, verifying at the same time the amount content and the isotopic composition of IRMM-1027m over the respective period of time [13, 14]. Furthermore, IRMM, ITU and the IAEA are engaged in mutual verification measurements of mixed uranium plutonium spike reference materials via an EC support task to the IAEA. In the frame of this support task verification measurements of randomly selected IRMM-1027 LSD spikes from different batches are performed sometimes up to two years after the certificate was issued, which is not only an external verification of the certified values but also a demonstration of the long-term stability of the IRMM-1027 series of LSD spikes. As a further proof of the long-term stability of the IRMM-1027 series, selected units of IRMM-1027m were set aside and stored under room temperature conditions for already almost four years. Regular visual inspection confirmed that the CAB in these units is still intact and does not show any sign of deterioration.

5.3 Estimation of uncertainties

Due to the chosen approach of demonstrating the stability by combining confirmation and homogeneity assessment and taking into account points 1) – 6) as listed in section 5, no additional contribution from the stability study to the expanded uncertainty of the certified values of IRMM-1027o is taken into account.

Underpinned by internal confirmation, external verification and long-term monitoring of the IRMM-1027 series of LSD spikes in CAB, short- and long-term stability have been demonstrated. The IRMM-1027o certificate is valid for three years from the date of signature. The validity may be extended after further tests on the stability of the spike material are carried out. The material has to be transported according to the legal requirements related to radioprotection measures for the transport of radioactive materials. It is recommended to store the units of IRMM-1027o at + 18 °C ± 5 °C in an upright position.

After the certification campaign, the material will be subjected to IRMM's regular stability monitoring programme to control its stability. At least one unit per year will be analysed in the IRMM nuclear laboratories to confirm the certified values.

6 Characterisation

The material characterisation is the process of determining the property values of a reference material.

The material characterisation was based on gravimetric preparation confirmed by independent analysis. The IRMM-1027o series of LSD spikes was prepared by dispensing an aliquot (about 2.5 g) of the mother solution into individual units by an automated robot system and subsequent drying. The masses of dispensed aliquots per unit before drying are given in Annex 13. The mother solution was prepared by gravimetric mixing of uranium and plutonium metals (see section 2.2). Each individual unit of IRMM-1027o LSD spike is certified for the mass of ^{239}Pu, ^{235}U and ^{238}U and the $n(^{234}U)/n(^{238}U)$, $n(^{235}U)/n(^{238}U)$, $n(^{240}Pu)/n(^{239}Pu)$, $n(^{241}Pu)/n(^{239}Pu)$, and $n(^{242}Pu)/n(^{239}Pu)$ amount ratios.

6.1 Purity of the starting materials

The purity of the starting materials (metals) was taken from the corresponding certificates (see Annexes 2-4). The purity of Pu MP2 metal was calculated for November 1, 2012 from the original purity of the CETAMA certificate (see Annex 15).

6.2 Masses of ^{239}Pu, ^{235}U and ^{238}U, Pu and U amount ratios and their uncertainties

The mass of ^{239}Pu, ^{235}U and ^{238}U and the Pu and U isotope amount ratios in each individual unit of IRMM-1027o are calculated from the mass fraction of uranium and plutonium in the mother solution, taking into account the mass of the metals and the solution, their purity and isotopic composition (e.g. isotope amount ratios), and the mass of an aliquot dispensed into each vial.

In Table 4 the data supporting the calculation of the masses of ^{239}Pu, ^{235}U and ^{238}U and Pu and U amount ratios per unit of IRMM-1027o are summarised.

Table 4: Gravimetric mixing to prepare the mother solution of IRMM-1027o

	MP2	EC NRM 101	NBL CRM-116	Mother solution
Mass [1] [g]	2.2495	53.507	13.435	3143.64
Purity [2] [g/g]	0.998510	0.99985	0.999672	/
Isotope amount ratios [3] [mol/mol]	$n(^{238}Pu)/n(^{239}Pu)$ 0.00003083 $n(^{240}Pu)/n(^{239}Pu)$ 0.0224324 $n(^{241}Pu)/n(^{239}Pu)$ 0.0002378 $n(^{242}Pu)/n(^{239}Pu)$ 0.00007570	$n(^{234}U)/n(^{238}U)$ 0.00005548 $n(^{235}U)/n(^{238}U)$ 0.0072593 $n(^{236}U)/n(^{238}U)$ 0.000000151	$n(^{234}U)/n(^{235}U)$ 0.0106853 $n(^{238}U)/n(^{235}U)$ 0.057975 $n(^{236}U)/n(^{235}U)$ 0.00448811	

[1] The masses of the metals are obtained from the weighing certificate, see Annex 14.

[2] The purity of the metals is obtained from the certificates, see Annexes 2-4.

[3] Amount ratios are obtained from the certificates, see Annexes 5-6, and the report of analysis, see Annex 7.

The uncertainties on the certified mass (u_{char}) of ^{239}Pu, ^{235}U and ^{238}U in the vial are composed of several contributions (Table 5), i.e. the uncertainty on the mass determination ($u_{char,1}$, $u_{char,2}$ and $u_{char,3}$), the uncertainty on the purity of the metals ($u_{char,4}$), and the uncertainties on the amount ratios ($u_{char,5}$). The complete and detailed calculations of the mass fractions, amount ratios and their uncertainty budgets are given in Annex 15 and Annex 16.

Table 5: Uncertainty budgets for the masses of ^{239}Pu, ^{235}U and ^{238}U in the vials of IRMM-1027o

	Standard uncertainty contribution					Combined relative uncertainty
	$u_{char,1}$ [1)] [g]	$u_{char,2}$ [2)] [g]	$u_{char,3}$ [3)] [g]	$u_{char,4}$ [4)] [g/g]	$u_{char,5}$ [5)] [mol/mol]	$u_{char,\ rel}$ [%]
^{239}Pu	0.0001	0.035	0.0003	0.000020	0.00000255	0.02373
^{235}U	0.001	0.035	0.0003	0.0000345	0.0000085	0.01445
^{238}U	0.003	0.035	0.0003	0.000025	0.0000018	0.01342

[1)] Standard uncertainty of the mass determination of the metals, see Annex 14.

[2)] Standard uncertainty of the mass determination of the mother solution, see Annex 14.

[3)] Standard uncertainty of the mass determination of an aliquot, see Annex 13.

[4)] Standard uncertainty of the purity of the metals, see Annexes 2-4.

[5)] Standard uncertainty of the largest amount ratio, for other amount ratios see Annexes 5-7.

6.3 Weighing and associated uncertainties

Masses of dispensed aliquots of the mother solution per unit used for the calculation of the certified values can be found in Annex 13. The dispensed masses were corrected for air buoyancy, taking into account the density of the air and the sample, the ambient humidity, temperature and pressure inside the glove box, and for the evaporation losses. Traceability to the SI is ensured by weighing a reference weight before and after dispensing a series of 96 units. The uncertainties on the dispensed mass are composed of several contributions, i.e. the uncertainty on the mass determination by an automated system, the uncertainty on the buoyancy correction, the uncertainty due to evaporation correction, and the uncertainty associated with the variability of the balance [6].

For the determination of the mass of the starting materials (metals) and the mother solution substitution weighing was used. In the substitution weighing, the mass of a sample is determined through a series of mass determinations of an unknown (U) and a reference weight (S). The so called "SUUS" method was applied. The uncertainty contributions in substitution weighing of the metals are the uncertainties associated with the calibrated weights (certificate), air buoyancy correction and the variability of the balance used in "SUUS" method.

6.4 Confirmation measurements

Twelve units of IRMM-1027o were randomly selected from the whole batch and analysed by ID-TIMS to confirm the uranium and plutonium amount contents from gravimetric preparation. To each of these vials, about 5 g of IRMM-046b mixed U/Pu spike in 5 M HNO_3 was weighed in and evaporated to dryness. Subsequently the isotopic equilibrium, chemical separation and isotopic measurements on Triton TIMS were carried out in the same manner as mentioned in Section 3.3 for the confirmation of the mother solution. The results of the confirmation measurements agreed well with the values from the gravimetrical preparation. The graphs are shown in Annex 12.

7 Value Assignment

Certified values are values that fulfil the highest standards of accuracy. Certified values for IRMM-1027o were assigned on the basis of gravimetric preparation as a primary method of

measurement. Full uncertainty budgets in accordance with the 'Guide to the Expression of Uncertainty in Measurement' [4] were established.

7.1 Certified values and their uncertainties

The certified values (masses of ^{239}Pu, ^{235}U and ^{238}U and Pu and U isotope amount ratios) are based on the masses of the metals, their purity and isotopic composition, the mass of the mother solution and the mass of an aliquot dispensed into the vials. All weighings were carried out with a set of calibrated weights, directly traceable to the kg prototype at BIPM, Paris, with the necessary corrections for air buoyancy effects.

The assigned uncertainty consists of uncertainties related to characterisation, u_{char} (Section 6), potential between-unit inhomogeneity, s_{bb} (Section 4.1) and potential degradation during transport (u_{sts}) and long-term storage, u_{lts} (Section 5). As described in Section 5 the uncertainty related to degradation during transport and long-term storage was found to be negligible. These different contributions were combined to estimate the expanded, relative uncertainty of the certified value ($U_{CRM, rel}$) with a coverage factor k as:

$$U_{CRM,rel} = k \cdot \sqrt{u_{char,rel}^2 + s_{bb,rel}^2} \qquad \textbf{Equation 4}$$

- u_{char} was estimated as described in Section 6
- s_{bb} was estimated as described in Section 4.1.

Because of the sufficient degrees of freedom of the different uncertainty contributions**,** a coverage factor k of 2 was applied to obtain the expanded uncertainties. The certified masses and their uncertainties for unit No. 1 are summarised in Table 6. The certified values of all 1215 units are given in Annex 1.

Table 6: Certified masses and their uncertainties for unit No.1 of IRMM-1027o

Mass	Certified value [mg]	$u_{char, rel}$ [%]	$s_{bb, rel}$ [%]	$U_{CRM, rel}$ [%]	U_{CRM} [1)] [mg]
^{239}Pu	1.7569	0.02373	0.01070	0.05207	0.0010
^{235}U	10.310	0.01445	0.01741	0.04525	0.005
^{238}U	43.081	0.01342	0.02586	0.05827	0.025

[1)] Expanded (k = 2) and rounded uncertainty.

The certified plutonium and uranium isotope amount ratios are summarised in Table 7.

Table 7: Certified isotope amount ratios and their uncertainties for IRMM-1027o LSD spikes

Isotope amount ratios	Certified value [1] [mol/mol]	U_{CRM} [2] [mol/mol]
$n(^{234}U)/n(^{238}U)$	0.0025682	0.0000007
$n(^{235}U)/n(^{238}U)$	0.24239	0.00005
$n(^{240}Pu)/n(^{239}Pu)$	0.022422	0.000006
$n(^{241}Pu)/n(^{239}Pu)$	0.0001793	0.0000024
$n(^{242}Pu)/n(^{239}Pu)$	0.0000757	0.0000008

[1] The reference date for the plutonium and uranium isotope amount ratios is November 1, 2012.

[2] Expanded (k = 2) and rounded uncertainty.

7.2 Additional material information

As additional information, the values for the plutonium and uranium amount contents, mass fractions and isotopic composition of the mother solution from gravimetric preparation are summarised in Table 8 and Table 9.

Table 8: Plutonium and uranium amount contents and mass fractions in the mother solution (sol) used for IRMM-1027o.

IRMM-1027o	Amount content		Mass fraction	
	Value [µmol/g sol]	Uncertainty [1] [µmol/g sol]	Value [mg/g sol]	Uncertainty [1] [mg/g sol]
^{235}U	17.441	0.004	4.0995	0.0009
^{238}U	71.959	0.010	17.1298	0.0022
U	89.661	0.010	21.2905	0.0023
^{239}Pu	2.9223	0.0012	0.69858	0.00030
Pu	2.9886	0.0012	0.71451	0.00030

[1] Expanded (k = 2) and rounded uncertainty.

Table 9: Plutonium and uranium isotopic mass fractions (expressed as $^{xxx}U/^{tot}U$ and $^{xxx}Pu/^{tot}Pu$) and isotope amount ratios in the mother solution (sol) used for IRMM-1027o.

	Isotopic mass fraction	
	Value [1] [%]	Uncertainty [2] [%]
$m(^{234}U)/m(U)\times100$	0.2031	0.0005
$m(^{235}U)/m(U)\times100$	19.255	0.004
$m(^{236}U)/m(U)\times100$	0.0843	0.0016
$m(^{238}U)/m(U)\times100$	80.458	0.004
$m(^{238}Pu)/m(Pu)\times100$	0.002867	0.000027
$m(^{239}Pu)/m(Pu)\times100$	97.7705	0.0006
$m(^{240}Pu)/m(Pu)\times100$	2.2014	0.0005
$m(^{241}Pu)/m(Pu)\times100$	0.01768	0.00023
$m(^{242}Pu)/m(Pu)\times100$	0.00750	0.00008
	Isotope amount ratios	
	Value [1] [mol/mol]	Uncertainty [2] [mol/mol]
$n(^{238}Pu)/n(^{239}Pu)$	0.00002945	0.00000028
$n(^{236}U)/n(^{238}U)$	0.00105586	0.00000024

[1] The reference date for the plutonium and uranium isotopic mass fractions and amount ratios is November 1, 2012.

[2] Expanded (k = 2) and rounded uncertainty.

8 Metrological traceability and commutability

8.1 Metrological traceability

Quantity value

The certified values are traceable to the values on the respective metal certificate (EC NRM 101, CETAMA MP2 and NBL CRM-116).

8.2 Commutability

Many measurement procedures include one or more steps, which are selecting specific (or specific groups) of analytes from the sample for the subsequent steps of the whole measurement process. Often the complete identity of these 'intermediate analytes' is not fully known or taken into account. Therefore, it is difficult to mimic all the analytically relevant properties of real samples within a CRM. The degree of equivalence in the analytical behaviour of real samples and a CRM with respect to various measurement procedures (methods) is summarised in a concept called 'commutability of a reference material'. There are various definitions expressing this concept. For instance, the CSLI Guideline C-53A [15] recommends the use of the following definition for the term *commutability*:

"The equivalence of the mathematical relationships among the results of different measurement procedures for an RM and for representative samples of the type intended to be measured."

The commutability of a CRM defines its fitness for use and, thus, is a crucial characteristic in case of the application of different measurement methods. When commutability of a CRM is not established in such cases, the results from routinely used methods cannot be legitimately compared with the certified value to determine whether a bias does not exist in calibration, nor can the CRM be used as a calibrant.

The IRMM-1027o is a dried nitrate in CAB certified for uranium and plutonium isotope amount ratios and masses of ^{235}U, ^{238}U and ^{239}Pu per unit. This CRM is tailor-made by IRMM for its intended use and serves as calibrant for uranium and plutonium IDMS measurements of samples from input solutions at reprocessing plants and is not intended to be used for other measurement methods.

9 Instructions for use

9.1 Safety information

The IRMM-1027o series contains radioactive material. The vials should be handled with great care and by experienced personnel in a laboratory suitably equipped for the safe handling of radioactive materials.

9.2 Storage conditions

The vials should be stored at + 18 °C ± 5 °C in an upright position.

Please note that the European Commission cannot be held responsible for changes that happen during storage of the material at the customer's premises, especially of opened vials.

9.3 Preparation and use of the material

The spike CRM has to be dissolved in the appropriate amount of acid (e.g. nitric acid with an amount of substance concentration c = 5 mol L^{-1}) or sample solution to ensure the isotopic equilibrium between the spike and the sample.

9.4 Minimum sample intake

The whole amount of sample per unit should be used for analysis.

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Annex 1: The masses of ^{235}U, ^{238}U and ^{239}Pu per unit of IRMM-1027o**.**

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0001	43.081	0.025	10.310	0.005	1.7569	0.0010
0002	43.086	0.025	10.311	0.005	1.7571	0.0010
0003	43.082	0.025	10.311	0.005	1.7570	0.0010
0004	43.093	0.025	10.313	0.005	1.7574	0.0010
0005	43.082	0.025	10.311	0.005	1.7570	0.0010
0006	43.063	0.025	10.306	0.005	1.7562	0.0010
0007	43.098	0.025	10.314	0.005	1.7576	0.0010
0008	43.086	0.025	10.311	0.005	1.7571	0.0010
0009	43.077	0.025	10.309	0.005	1.7568	0.0010
0010	43.077	0.025	10.309	0.005	1.7568	0.0010
0011	43.062	0.025	10.306	0.005	1.7561	0.0010
0012	43.093	0.025	10.313	0.005	1.7574	0.0010
0013	43.038	0.025	10.300	0.005	1.7551	0.0010
0014	43.045	0.025	10.302	0.005	1.7554	0.0010
0015	43.063	0.025	10.306	0.005	1.7562	0.0010
0016	43.069	0.025	10.307	0.005	1.7564	0.0010
0017	43.081	0.025	10.310	0.005	1.7569	0.0010
0018	43.065	0.025	10.307	0.005	1.7563	0.0010
0019	43.063	0.025	10.306	0.005	1.7562	0.0010
0020	43.053	0.025	10.304	0.005	1.7558	0.0010
0021	43.129	0.025	10.322	0.005	1.7588	0.0010
0022	43.081	0.025	10.310	0.005	1.7569	0.0010
0023	43.051	0.025	10.303	0.005	1.7557	0.0010
0024	43.074	0.025	10.309	0.005	1.7566	0.0010
0025	43.074	0.025	10.309	0.005	1.7566	0.0010
0026	43.081	0.025	10.310	0.005	1.7569	0.0010
0027	43.057	0.025	10.304	0.005	1.7559	0.0010
0028	43.039	0.025	10.300	0.005	1.7552	0.0010
0029	43.094	0.025	10.313	0.005	1.7575	0.0010
0030	43.058	0.025	10.305	0.005	1.7560	0.0010
0031	43.062	0.025	10.306	0.005	1.7561	0.0010
0032	43.067	0.025	10.307	0.005	1.7563	0.0010
0033	43.063	0.025	10.306	0.005	1.7562	0.0010
0034	43.081	0.025	10.310	0.005	1.7569	0.0010
0035	43.053	0.025	10.304	0.005	1.7558	0.0010
0036	43.074	0.025	10.309	0.005	1.7566	0.0010
0037	43.063	0.025	10.306	0.005	1.7562	0.0010
0038	43.094	0.025	10.313	0.005	1.7575	0.0010
0039	43.021	0.025	10.296	0.005	1.7544	0.0010
0040	43.091	0.025	10.313	0.005	1.7573	0.0010
0041	43.043	0.025	10.301	0.005	1.7554	0.0010
0042	43.089	0.025	10.312	0.005	1.7572	0.0010
0043	43.072	0.025	10.308	0.005	1.7565	0.0010
0044	43.026	0.025	10.297	0.005	1.7547	0.0010
0045	43.060	0.025	10.305	0.005	1.7561	0.0010
0046	43.065	0.025	10.307	0.005	1.7563	0.0010
0047	43.084	0.025	10.311	0.005	1.7570	0.0010
0048	43.055	0.025	10.304	0.005	1.7558	0.0010
0049	43.060	0.025	10.305	0.005	1.7561	0.0010
0050	43.060	0.025	10.305	0.005	1.7561	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0051	43.055	0.025	10.304	0.005	1.7558	0.0010
0052	43.093	0.025	10.313	0.005	1.7574	0.0010
0053	43.072	0.025	10.308	0.005	1.7565	0.0010
0054	43.077	0.025	10.309	0.005	1.7568	0.0010
0055	43.062	0.025	10.306	0.005	1.7561	0.0010
0056	43.089	0.025	10.312	0.005	1.7572	0.0010
0057	43.055	0.025	10.304	0.005	1.7558	0.0010
0058	43.074	0.025	10.309	0.005	1.7566	0.0010
0059	43.069	0.025	10.307	0.005	1.7564	0.0010
0060	43.077	0.025	10.309	0.005	1.7568	0.0010
0061	43.070	0.025	10.308	0.005	1.7565	0.0010
0062	43.084	0.025	10.311	0.005	1.7570	0.0010
0063	43.048	0.025	10.302	0.005	1.7556	0.0010
0064	43.082	0.025	10.311	0.005	1.7570	0.0010
0065	43.057	0.025	10.304	0.005	1.7559	0.0010
0066	43.062	0.025	10.306	0.005	1.7561	0.0010
0067	43.070	0.025	10.308	0.005	1.7565	0.0010
0068	43.075	0.025	10.309	0.005	1.7567	0.0010
0069	43.089	0.025	10.312	0.005	1.7572	0.0010
0070	43.048	0.025	10.302	0.005	1.7556	0.0010
0071	43.053	0.025	10.304	0.005	1.7558	0.0010
0072	43.072	0.025	10.308	0.005	1.7565	0.0010
0073	43.063	0.025	10.306	0.005	1.7562	0.0010
0074	43.077	0.025	10.309	0.005	1.7568	0.0010
0075	43.057	0.025	10.304	0.005	1.7559	0.0010
0076	43.103	0.025	10.316	0.005	1.7578	0.0010
0077	43.045	0.025	10.302	0.005	1.7554	0.0010
0078	43.060	0.025	10.305	0.005	1.7561	0.0010
0079	43.082	0.025	10.311	0.005	1.7570	0.0010
0080	43.062	0.025	10.306	0.005	1.7561	0.0010
0081	43.069	0.025	10.307	0.005	1.7564	0.0010
0082	43.067	0.025	10.307	0.005	1.7563	0.0010
0083	43.079	0.025	10.310	0.005	1.7568	0.0010
0084	43.063	0.025	10.306	0.005	1.7562	0.0010
0085	43.077	0.025	10.309	0.005	1.7568	0.0010
0086	43.067	0.025	10.307	0.005	1.7563	0.0010
0087	43.074	0.025	10.309	0.005	1.7566	0.0010
0088	43.075	0.025	10.309	0.005	1.7567	0.0010
0089	43.065	0.025	10.307	0.005	1.7563	0.0010
0090	43.075	0.025	10.309	0.005	1.7567	0.0010
0091	43.075	0.025	10.309	0.005	1.7567	0.0010
0092	43.045	0.025	10.302	0.005	1.7554	0.0010
0093	43.099	0.025	10.315	0.005	1.7577	0.0010
0094	43.067	0.025	10.307	0.005	1.7563	0.0010
0095	43.086	0.025	10.311	0.005	1.7571	0.0010
0096	43.069	0.025	10.307	0.005	1.7564	0.0010
0097	43.413	0.025	10.390	0.005	1.7705	0.0010
0098	43.444	0.025	10.397	0.005	1.7717	0.0010
0099	43.415	0.025	10.390	0.005	1.7705	0.0010
0100	43.432	0.025	10.394	0.005	1.7712	0.0010

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0101	43.417	0.025	10.391	0.005	1.7706	0.0010
0102	43.435	0.025	10.395	0.005	1.7714	0.0010
0103	43.427	0.025	10.393	0.005	1.7710	0.0010
0104	43.437	0.025	10.396	0.005	1.7714	0.0010
0105	43.413	0.025	10.390	0.005	1.7705	0.0010
0106	43.391	0.025	10.384	0.005	1.7695	0.0010
0107	43.420	0.025	10.391	0.005	1.7707	0.0010
0108	43.475	0.025	10.405	0.005	1.7730	0.0010
0109	43.417	0.025	10.391	0.005	1.7706	0.0010
0110	43.435	0.025	10.395	0.005	1.7714	0.0010
0111	43.444	0.025	10.397	0.005	1.7717	0.0010
0112	43.410	0.025	10.389	0.005	1.7703	0.0010
0113	43.439	0.025	10.396	0.005	1.7715	0.0010
0114	43.435	0.025	10.395	0.005	1.7714	0.0010
0115	43.422	0.025	10.392	0.005	1.7708	0.0010
0116	43.454	0.025	10.400	0.005	1.7721	0.0010
0117	43.413	0.025	10.390	0.005	1.7705	0.0010
0118	43.422	0.025	10.392	0.005	1.7708	0.0010
0119	43.446	0.025	10.398	0.005	1.7718	0.0010
0120	43.413	0.025	10.390	0.005	1.7705	0.0010
0121	43.442	0.025	10.397	0.005	1.7716	0.0010
0122	43.432	0.025	10.394	0.005	1.7712	0.0010
0123	43.405	0.025	10.388	0.005	1.7701	0.0010
0124	43.439	0.025	10.396	0.005	1.7715	0.0010
0125	43.430	0.025	10.394	0.005	1.7712	0.0010
0126	43.427	0.025	10.393	0.005	1.7710	0.0010
0127	43.434	0.025	10.395	0.005	1.7713	0.0010
0128	43.430	0.025	10.394	0.005	1.7712	0.0010
0129	43.439	0.025	10.396	0.005	1.7715	0.0010
0130	43.403	0.025	10.387	0.005	1.7700	0.0010
0131	43.437	0.025	10.396	0.005	1.7714	0.0010
0132	43.422	0.025	10.392	0.005	1.7708	0.0010
0133	43.435	0.025	10.395	0.005	1.7714	0.0010
0134	43.417	0.025	10.391	0.005	1.7706	0.0010
0135	43.449	0.025	10.398	0.005	1.7719	0.0010
0136	43.447	0.025	10.398	0.005	1.7719	0.0010
0137	43.427	0.025	10.393	0.005	1.7710	0.0010
0138	43.441	0.025	10.396	0.005	1.7716	0.0010
0139	43.451	0.025	10.399	0.005	1.7720	0.0010
0140	43.422	0.025	10.392	0.005	1.7708	0.0010
0141	43.430	0.025	10.394	0.005	1.7712	0.0010
0142	43.444	0.025	10.397	0.005	1.7717	0.0010
0143	43.465	0.025	10.402	0.005	1.7726	0.0010
0144	43.430	0.025	10.394	0.005	1.7712	0.0010
0145	43.449	0.025	10.398	0.005	1.7719	0.0010
0146	43.408	0.025	10.389	0.005	1.7702	0.0010
0147	43.386	0.025	10.383	0.005	1.7693	0.0010
0148	42.619	0.025	10.200	0.005	1.7381	0.0010
0149	43.425	0.025	10.393	0.005	1.7709	0.0010
0150	43.449	0.025	10.398	0.005	1.7719	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0151	43.372	0.025	10.380	0.005	1.7688	0.0010
0152	43.482	0.025	10.406	0.005	1.7733	0.0010
0153	43.406	0.025	10.388	0.005	1.7702	0.0010
0154	42.602	0.025	10.196	0.005	1.7374	0.0010
0155	43.459	0.025	10.401	0.005	1.7723	0.0010
0156	43.456	0.025	10.400	0.005	1.7722	0.0010
0157	43.442	0.025	10.397	0.005	1.7716	0.0010
0158	43.406	0.025	10.388	0.005	1.7702	0.0010
0159	43.459	0.025	10.401	0.005	1.7723	0.0010
0160	43.442	0.025	10.397	0.005	1.7716	0.0010
0161	43.434	0.025	10.395	0.005	1.7713	0.0010
0162	43.453	0.025	10.399	0.005	1.7721	0.0010
0163	43.453	0.025	10.399	0.005	1.7721	0.0010
0164	43.415	0.025	10.390	0.005	1.7705	0.0010
0165	43.437	0.025	10.396	0.005	1.7714	0.0010
0166	43.459	0.025	10.401	0.005	1.7723	0.0010
0167	43.449	0.025	10.398	0.005	1.7719	0.0010
0168	43.422	0.025	10.392	0.005	1.7708	0.0010
0169	43.413	0.025	10.390	0.005	1.7705	0.0010
0170	43.453	0.025	10.399	0.005	1.7721	0.0010
0171	43.439	0.025	10.396	0.005	1.7715	0.0010
0172	43.437	0.025	10.396	0.005	1.7714	0.0010
0173	43.441	0.025	10.396	0.005	1.7716	0.0010
0174	43.456	0.025	10.400	0.005	1.7722	0.0010
0175	43.423	0.025	10.392	0.005	1.7709	0.0010
0176	43.453	0.025	10.399	0.005	1.7721	0.0010
0177	43.437	0.025	10.396	0.005	1.7714	0.0010
0178	43.422	0.025	10.392	0.005	1.7708	0.0010
0179	43.429	0.025	10.393	0.005	1.7711	0.0010
0180	43.459	0.025	10.401	0.005	1.7723	0.0010
0181	43.430	0.025	10.394	0.005	1.7712	0.0010
0182	43.422	0.025	10.392	0.005	1.7708	0.0010
0183	43.451	0.025	10.399	0.005	1.7720	0.0010
0184	43.434	0.025	10.395	0.005	1.7713	0.0010
0185	43.425	0.025	10.393	0.005	1.7709	0.0010
0186	43.468	0.025	10.403	0.005	1.7727	0.0010
0187	43.413	0.025	10.390	0.005	1.7705	0.0010
0188	43.423	0.025	10.392	0.005	1.7709	0.0010
0189	43.429	0.025	10.393	0.005	1.7711	0.0010
0190	43.413	0.025	10.390	0.005	1.7705	0.0010
0191	43.423	0.025	10.392	0.005	1.7709	0.0010
0192	43.439	0.025	10.396	0.005	1.7715	0.0010
0193	43.444	0.025	10.397	0.005	1.7717	0.0010
0194	43.410	0.025	10.389	0.005	1.7703	0.0010
0195	43.420	0.025	10.391	0.005	1.7707	0.0010
0196	43.432	0.025	10.394	0.005	1.7712	0.0010
0197	43.415	0.025	10.390	0.005	1.7705	0.0010
0198	43.456	0.025	10.400	0.005	1.7722	0.0010
0199	43.454	0.025	10.400	0.005	1.7721	0.0010
0200	43.398	0.025	10.386	0.005	1.7698	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0201	43.434	0.025	10.395	0.005	1.7713	0.0010
0202	43.422	0.025	10.392	0.005	1.7708	0.0010
0203	42.612	0.025	10.198	0.005	1.7378	0.0010
0204	43.403	0.025	10.387	0.005	1.7700	0.0010
0205	43.446	0.025	10.398	0.005	1.7718	0.0010
0206	43.444	0.025	10.397	0.005	1.7717	0.0010
0207	43.428	0.025	10.393	0.005	1.7711	0.0010
0208	43.401	0.025	10.387	0.005	1.7700	0.0010
0209	43.434	0.025	10.395	0.005	1.7713	0.0010
0210	43.473	0.025	10.404	0.005	1.7729	0.0010
0211	43.410	0.025	10.389	0.005	1.7703	0.0010
0212	43.391	0.025	10.384	0.005	1.7695	0.0010
0213	43.434	0.025	10.395	0.005	1.7713	0.0010
0214	43.432	0.025	10.394	0.005	1.7712	0.0010
0215	43.430	0.025	10.394	0.005	1.7711	0.0010
0216	43.432	0.025	10.394	0.005	1.7712	0.0010
0217	43.464	0.025	10.402	0.005	1.7725	0.0010
0218	43.403	0.025	10.387	0.005	1.7700	0.0010
0219	43.468	0.025	10.403	0.005	1.7727	0.0010
0220	43.389	0.025	10.384	0.005	1.7695	0.0010
0221	43.427	0.025	10.393	0.005	1.7710	0.0010
0222	43.470	0.025	10.403	0.005	1.7728	0.0010
0223	43.391	0.025	10.384	0.005	1.7695	0.0010
0224	43.404	0.025	10.388	0.005	1.7701	0.0010
0225	43.401	0.025	10.387	0.005	1.7700	0.0010
0226	43.470	0.025	10.403	0.005	1.7728	0.0010
0227	43.430	0.025	10.394	0.005	1.7711	0.0010
0228	43.413	0.025	10.390	0.005	1.7704	0.0010
0229	43.454	0.025	10.400	0.005	1.7721	0.0010
0230	43.410	0.025	10.389	0.005	1.7703	0.0010
0231	43.428	0.025	10.393	0.005	1.7711	0.0010
0232	43.451	0.025	10.399	0.005	1.7720	0.0010
0233	43.430	0.025	10.394	0.005	1.7711	0.0010
0234	43.392	0.025	10.385	0.005	1.7696	0.0010
0235	43.413	0.025	10.390	0.005	1.7704	0.0010
0236	43.466	0.025	10.402	0.005	1.7726	0.0010
0237	43.387	0.025	10.384	0.005	1.7694	0.0010
0238	43.427	0.025	10.393	0.005	1.7710	0.0010
0239	43.391	0.025	10.384	0.005	1.7695	0.0010
0240	43.432	0.025	10.394	0.005	1.7712	0.0010
0241	43.446	0.025	10.398	0.005	1.7718	0.0010
0242	43.434	0.025	10.395	0.005	1.7713	0.0010
0243	43.408	0.025	10.389	0.005	1.7702	0.0010
0244	43.422	0.025	10.392	0.005	1.7708	0.0010
0245	43.386	0.025	10.383	0.005	1.7693	0.0010
0246	42.602	0.025	10.196	0.005	1.7374	0.0010
0247	43.415	0.025	10.390	0.005	1.7705	0.0010
0248	43.459	0.025	10.401	0.005	1.7723	0.0010
0249	43.387	0.025	10.384	0.005	1.7694	0.0010
0250	43.447	0.025	10.398	0.005	1.7718	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0251	43.389	0.025	10.384	0.005	1.7695	0.0010
0252	42.600	0.025	10.195	0.005	1.7373	0.0010
0253	43.370	0.025	10.380	0.005	1.7687	0.0010
0254	43.428	0.025	10.393	0.005	1.7711	0.0010
0255	42.599	0.025	10.195	0.005	1.7372	0.0010
0256	43.396	0.025	10.386	0.005	1.7697	0.0010
0257	43.416	0.025	10.391	0.005	1.7706	0.0010
0258	43.458	0.025	10.400	0.005	1.7723	0.0010
0259	43.372	0.025	10.380	0.005	1.7688	0.0010
0260	43.468	0.025	10.403	0.005	1.7727	0.0010
0261	43.442	0.025	10.397	0.005	1.7716	0.0010
0262	43.430	0.025	10.394	0.005	1.7711	0.0010
0263	43.415	0.025	10.390	0.005	1.7705	0.0010
0264	43.432	0.025	10.394	0.005	1.7712	0.0010
0265	43.432	0.025	10.394	0.005	1.7712	0.0010
0266	43.430	0.025	10.394	0.005	1.7711	0.0010
0267	43.387	0.025	10.384	0.005	1.7694	0.0010
0268	43.408	0.025	10.389	0.005	1.7702	0.0010
0269	43.434	0.025	10.395	0.005	1.7713	0.0010
0270	43.415	0.025	10.390	0.005	1.7705	0.0010
0271	43.392	0.025	10.385	0.005	1.7696	0.0010
0272	43.406	0.025	10.388	0.005	1.7702	0.0010
0273	43.434	0.025	10.395	0.005	1.7713	0.0010
0274	43.432	0.025	10.394	0.005	1.7712	0.0010
0275	43.437	0.025	10.396	0.005	1.7714	0.0010
0276	43.399	0.025	10.386	0.005	1.7699	0.0010
0277	43.439	0.025	10.396	0.005	1.7715	0.0010
0278	43.372	0.025	10.380	0.005	1.7688	0.0010
0279	43.437	0.025	10.396	0.005	1.7714	0.0010
0280	42.602	0.025	10.196	0.005	1.7374	0.0010
0281	43.398	0.025	10.386	0.005	1.7698	0.0010
0282	43.396	0.025	10.386	0.005	1.7697	0.0010
0283	43.422	0.025	10.392	0.005	1.7708	0.0010
0284	43.410	0.025	10.389	0.005	1.7703	0.0010
0285	43.427	0.025	10.393	0.005	1.7710	0.0010
0286	43.422	0.025	10.392	0.005	1.7708	0.0010
0287	43.432	0.025	10.394	0.005	1.7712	0.0010
0288	43.379	0.025	10.382	0.005	1.7690	0.0010
0289	42.635	0.025	10.203	0.005	1.7387	0.0010
0290	43.372	0.025	10.380	0.005	1.7688	0.0010
0291	43.380	0.025	10.382	0.005	1.7691	0.0010
0292	43.404	0.025	10.388	0.005	1.7701	0.0010
0293	43.320	0.025	10.368	0.005	1.7667	0.0010
0294	42.611	0.025	10.198	0.005	1.7377	0.0010
0295	43.326	0.025	10.369	0.005	1.7669	0.0010
0296	43.389	0.025	10.384	0.005	1.7695	0.0010
0297	43.446	0.025	10.398	0.005	1.7718	0.0010
0298	43.377	0.025	10.381	0.005	1.7690	0.0010
0299	43.399	0.025	10.386	0.005	1.7699	0.0010
0300	43.435	0.025	10.395	0.005	1.7714	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0301	43.389	0.025	10.384	0.005	1.7695	0.0010
0302	43.401	0.025	10.387	0.005	1.7700	0.0010
0303	43.399	0.025	10.386	0.005	1.7699	0.0010
0304	43.428	0.025	10.393	0.005	1.7711	0.0010
0305	43.379	0.025	10.382	0.005	1.7690	0.0010
0306	43.360	0.025	10.377	0.005	1.7683	0.0010
0307	43.430	0.025	10.394	0.005	1.7711	0.0010
0308	43.399	0.025	10.386	0.005	1.7699	0.0010
0309	43.425	0.025	10.393	0.005	1.7709	0.0010
0310	43.355	0.025	10.376	0.005	1.7681	0.0010
0311	43.398	0.025	10.386	0.005	1.7698	0.0010
0312	43.396	0.025	10.386	0.005	1.7697	0.0010
0313	43.401	0.025	10.387	0.005	1.7700	0.0010
0314	43.389	0.025	10.384	0.005	1.7695	0.0010
0315	43.420	0.025	10.391	0.005	1.7707	0.0010
0316	43.432	0.025	10.394	0.005	1.7712	0.0010
0317	43.363	0.025	10.378	0.005	1.7684	0.0010
0318	43.391	0.025	10.384	0.005	1.7695	0.0010
0319	43.404	0.025	10.388	0.005	1.7701	0.0010
0320	43.428	0.025	10.393	0.005	1.7711	0.0010
0321	43.416	0.025	10.391	0.005	1.7706	0.0010
0322	43.355	0.025	10.376	0.005	1.7681	0.0010
0323	43.411	0.025	10.389	0.005	1.7704	0.0010
0324	43.458	0.025	10.400	0.005	1.7723	0.0010
0325	43.362	0.025	10.377	0.005	1.7683	0.0010
0326	43.375	0.025	10.381	0.005	1.7689	0.0010
0327	43.440	0.025	10.396	0.005	1.7716	0.0010
0328	43.375	0.025	10.381	0.005	1.7689	0.0010
0329	43.384	0.025	10.383	0.005	1.7693	0.0010
0330	42.633	0.025	10.203	0.005	1.7386	0.0010
0331	43.365	0.025	10.378	0.005	1.7685	0.0010
0332	43.365	0.025	10.378	0.005	1.7685	0.0010
0333	43.428	0.025	10.393	0.005	1.7711	0.0010
0334	43.350	0.025	10.375	0.005	1.7679	0.0010
0335	42.659	0.025	10.209	0.005	1.7397	0.0010
0336	43.308	0.025	10.365	0.005	1.7662	0.0010
0337	43.487	0.025	10.407	0.005	1.7735	0.0010
0338	43.387	0.025	10.384	0.005	1.7694	0.0010
0339	43.365	0.025	10.378	0.005	1.7685	0.0010
0340	43.408	0.025	10.389	0.005	1.7702	0.0010
0341	43.420	0.025	10.391	0.005	1.7707	0.0010
0342	42.607	0.025	10.197	0.005	1.7376	0.0010
0343	43.398	0.025	10.386	0.005	1.7698	0.0010
0344	43.404	0.025	10.388	0.005	1.7701	0.0010
0345	43.427	0.025	10.393	0.005	1.7710	0.0010
0346	43.380	0.025	10.382	0.005	1.7691	0.0010
0347	43.408	0.025	10.389	0.005	1.7702	0.0010
0348	43.420	0.025	10.391	0.005	1.7707	0.0010
0349	43.437	0.025	10.395	0.005	1.7714	0.0010
0350	43.389	0.025	10.384	0.005	1.7695	0.0010

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0351	43.452	0.025	10.399	0.005	1.7721	0.0010
0352	43.346	0.025	10.374	0.005	1.7677	0.0010
0353	43.452	0.025	10.399	0.005	1.7721	0.0010
0354	43.348	0.025	10.374	0.005	1.7678	0.0010
0355	43.456	0.025	10.400	0.005	1.7722	0.0010
0356	43.363	0.025	10.378	0.005	1.7684	0.0010
0357	42.600	0.025	10.195	0.005	1.7373	0.0010
0358	43.343	0.025	10.373	0.005	1.7676	0.0010
0359	43.392	0.025	10.385	0.005	1.7696	0.0010
0360	43.399	0.025	10.386	0.005	1.7699	0.0010
0361	43.415	0.025	10.390	0.005	1.7705	0.0010
0362	43.430	0.025	10.394	0.005	1.7711	0.0010
0363	43.362	0.025	10.377	0.005	1.7683	0.0010
0364	43.411	0.025	10.389	0.005	1.7704	0.0010
0365	43.416	0.025	10.391	0.005	1.7706	0.0010
0366	42.612	0.025	10.198	0.005	1.7378	0.0010
0367	43.327	0.025	10.369	0.005	1.7669	0.0010
0368	42.604	0.025	10.196	0.005	1.7374	0.0010
0369	43.315	0.025	10.366	0.005	1.7665	0.0010
0370	43.447	0.025	10.398	0.005	1.7718	0.0010
0371	43.360	0.025	10.377	0.005	1.7683	0.0010
0372	43.348	0.025	10.374	0.005	1.7678	0.0010
0373	43.459	0.025	10.401	0.005	1.7723	0.0010
0374	43.423	0.025	10.392	0.005	1.7709	0.0010
0375	42.609	0.025	10.197	0.005	1.7377	0.0010
0376	43.356	0.025	10.376	0.005	1.7681	0.0010
0377	43.365	0.025	10.378	0.005	1.7685	0.0010
0378	43.492	0.025	10.409	0.005	1.7737	0.0010
0379	43.420	0.025	10.391	0.005	1.7707	0.0010
0380	43.332	0.025	10.370	0.005	1.7672	0.0010
0381	43.440	0.025	10.396	0.005	1.7716	0.0010
0382	43.403	0.025	10.387	0.005	1.7700	0.0010
0383	43.370	0.025	10.379	0.005	1.7687	0.0010
0384	43.386	0.025	10.383	0.005	1.7693	0.0010
0385	43.398	0.025	10.386	0.005	1.7698	0.0010
0386	42.612	0.025	10.198	0.005	1.7378	0.0010
0387	43.377	0.025	10.381	0.005	1.7690	0.0010
0388	42.605	0.025	10.197	0.005	1.7375	0.0010
0389	43.398	0.025	10.386	0.005	1.7698	0.0010
0390	43.343	0.025	10.373	0.005	1.7676	0.0010
0391	43.473	0.025	10.404	0.005	1.7729	0.0010
0392	43.389	0.025	10.384	0.005	1.7695	0.0010
0393	43.350	0.025	10.375	0.005	1.7679	0.0010
0394	43.401	0.025	10.387	0.005	1.7700	0.0010
0395	43.507	0.025	10.412	0.005	1.7743	0.0010
0396	43.389	0.025	10.384	0.005	1.7695	0.0010
0397	43.334	0.025	10.371	0.005	1.7672	0.0010
0398	43.423	0.025	10.392	0.005	1.7709	0.0010
0399	43.396	0.025	10.386	0.005	1.7697	0.0010
0400	42.611	0.025	10.198	0.005	1.7377	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0401	43.339	0.025	10.372	0.005	1.7674	0.0010
0402	43.387	0.025	10.384	0.005	1.7694	0.0010
0403	43.375	0.025	10.381	0.005	1.7689	0.0010
0404	43.461	0.025	10.401	0.005	1.7724	0.0010
0405	43.355	0.025	10.376	0.005	1.7681	0.0010
0406	43.415	0.025	10.390	0.005	1.7705	0.0010
0407	43.478	0.025	10.405	0.005	1.7731	0.0010
0408	43.334	0.025	10.371	0.005	1.7672	0.0010
0409	43.382	0.025	10.382	0.005	1.7692	0.0010
0410	43.528	0.025	10.417	0.005	1.7751	0.0010
0411	43.298	0.025	10.362	0.005	1.7658	0.0010
0412	43.386	0.025	10.383	0.005	1.7693	0.0010
0413	43.425	0.025	10.393	0.005	1.7709	0.0010
0414	43.355	0.025	10.376	0.005	1.7681	0.0010
0415	43.427	0.025	10.393	0.005	1.7710	0.0010
0416	43.327	0.025	10.369	0.005	1.7669	0.0010
0417	42.638	0.025	10.204	0.005	1.7388	0.0010
0418	43.380	0.025	10.382	0.005	1.7691	0.0010
0419	43.420	0.025	10.391	0.005	1.7707	0.0010
0420	43.298	0.025	10.362	0.005	1.7658	0.0010
0421	43.449	0.025	10.398	0.005	1.7719	0.0010
0422	43.336	0.025	10.371	0.005	1.7673	0.0010
0423	43.458	0.025	10.400	0.005	1.7723	0.0010
0424	43.314	0.025	10.366	0.005	1.7664	0.0010
0425	43.363	0.025	10.378	0.005	1.7684	0.0010
0426	43.380	0.025	10.382	0.005	1.7691	0.0010
0427	42.629	0.025	10.202	0.005	1.7385	0.0010
0428	43.336	0.025	10.371	0.005	1.7673	0.0010
0429	43.440	0.025	10.396	0.005	1.7716	0.0010
0430	43.355	0.025	10.376	0.005	1.7681	0.0010
0431	43.392	0.025	10.385	0.005	1.7696	0.0010
0432	43.404	0.025	10.388	0.005	1.7701	0.0010
0433	43.379	0.025	10.382	0.005	1.7690	0.0010
0434	43.404	0.025	10.388	0.005	1.7701	0.0010
0435	43.456	0.025	10.400	0.005	1.7722	0.0010
0436	43.290	0.025	10.360	0.005	1.7654	0.0010
0437	43.483	0.025	10.407	0.005	1.7733	0.0010
0438	43.293	0.025	10.361	0.005	1.7656	0.0010
0439	43.475	0.025	10.405	0.005	1.7730	0.0010
0440	43.300	0.025	10.363	0.005	1.7658	0.0010
0441	43.363	0.025	10.378	0.005	1.7684	0.0010
0442	43.411	0.025	10.389	0.005	1.7704	0.0010
0443	43.427	0.025	10.393	0.005	1.7710	0.0010
0444	43.490	0.025	10.408	0.005	1.7736	0.0010
0445	43.276	0.025	10.357	0.005	1.7649	0.0010
0446	43.391	0.025	10.384	0.005	1.7695	0.0010
0447	43.406	0.025	10.388	0.005	1.7702	0.0010
0448	43.430	0.025	10.394	0.005	1.7711	0.0010
0449	43.290	0.025	10.360	0.005	1.7654	0.0010
0450	43.471	0.025	10.404	0.005	1.7728	0.0010

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0451	43.362	0.025	10.377	0.005	1.7683	0.0010
0452	43.440	0.025	10.396	0.005	1.7716	0.0010
0453	43.377	0.025	10.381	0.005	1.7690	0.0010
0454	43.368	0.025	10.379	0.005	1.7686	0.0010
0455	43.396	0.025	10.386	0.005	1.7697	0.0010
0456	43.406	0.025	10.388	0.005	1.7702	0.0010
0457	43.358	0.025	10.377	0.005	1.7682	0.0010
0458	43.389	0.025	10.384	0.005	1.7695	0.0010
0459	43.344	0.025	10.373	0.005	1.7676	0.0010
0460	42.628	0.025	10.202	0.005	1.7384	0.0010
0461	43.358	0.025	10.377	0.005	1.7682	0.0010
0462	43.346	0.025	10.374	0.005	1.7677	0.0010
0463	43.442	0.025	10.397	0.005	1.7716	0.0010
0464	43.343	0.025	10.373	0.005	1.7676	0.0010
0465	43.507	0.025	10.412	0.005	1.7743	0.0010
0466	43.255	0.025	10.352	0.005	1.7640	0.0010
0467	42.597	0.025	10.194	0.005	1.7372	0.0010
0468	43.338	0.025	10.372	0.005	1.7674	0.0010
0469	43.382	0.025	10.382	0.005	1.7692	0.0010
0470	43.377	0.025	10.381	0.005	1.7690	0.0010
0471	43.420	0.025	10.391	0.005	1.7707	0.0010
0472	43.432	0.025	10.394	0.005	1.7712	0.0010
0473	43.382	0.025	10.382	0.005	1.7692	0.0010
0474	43.362	0.025	10.377	0.005	1.7683	0.0010
0475	42.616	0.025	10.199	0.005	1.7379	0.0010
0476	43.317	0.025	10.367	0.005	1.7665	0.0010
0477	43.351	0.025	10.375	0.005	1.7679	0.0010
0478	42.629	0.025	10.202	0.005	1.7385	0.0010
0479	43.398	0.025	10.386	0.005	1.7698	0.0010
0480	43.254	0.025	10.352	0.005	1.7639	0.0010
0481	42.600	0.025	10.195	0.005	1.7373	0.0010
0482	43.322	0.025	10.368	0.005	1.7667	0.0010
0483	43.404	0.025	10.388	0.005	1.7701	0.0010
0484	43.385	0.025	10.383	0.005	1.7693	0.0010
0485	43.478	0.025	10.405	0.005	1.7731	0.0010
0486	43.301	0.025	10.363	0.005	1.7659	0.0010
0487	43.379	0.025	10.382	0.005	1.7690	0.0010
0488	43.404	0.025	10.388	0.005	1.7701	0.0010
0489	43.337	0.025	10.372	0.005	1.7674	0.0010
0490	43.356	0.025	10.376	0.005	1.7681	0.0010
0491	42.679	0.025	10.214	0.005	1.7405	0.0010
0492	43.325	0.025	10.369	0.005	1.7669	0.0010
0493	43.391	0.025	10.384	0.005	1.7695	0.0010
0494	43.421	0.025	10.392	0.005	1.7708	0.0010
0495	43.457	0.025	10.400	0.005	1.7723	0.0010
0496	43.269	0.025	10.355	0.005	1.7646	0.0010
0497	43.361	0.025	10.377	0.005	1.7683	0.0010
0498	43.439	0.025	10.396	0.005	1.7715	0.0010
0499	43.415	0.025	10.390	0.005	1.7705	0.0010
0500	43.324	0.025	10.368	0.005	1.7668	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0501	43.509	0.025	10.413	0.005	1.7744	0.0010
0502	43.301	0.025	10.363	0.005	1.7659	0.0010
0503	43.360	0.025	10.377	0.005	1.7683	0.0010
0504	43.315	0.025	10.366	0.005	1.7665	0.0010
0505	43.512	0.025	10.414	0.005	1.7745	0.0010
0506	43.262	0.025	10.354	0.005	1.7643	0.0010
0507	43.360	0.025	10.377	0.005	1.7683	0.0010
0508	43.451	0.025	10.399	0.005	1.7720	0.0010
0509	43.319	0.025	10.367	0.005	1.7666	0.0010
0510	42.592	0.025	10.193	0.005	1.7370	0.0010
0511	43.339	0.025	10.372	0.005	1.7674	0.0010
0512	43.375	0.025	10.381	0.005	1.7689	0.0010
0513	43.351	0.025	10.375	0.005	1.7679	0.0010
0514	43.397	0.025	10.386	0.005	1.7698	0.0010
0515	43.358	0.025	10.377	0.005	1.7682	0.0010
0516	43.373	0.025	10.380	0.005	1.7688	0.0010
0517	43.379	0.025	10.382	0.005	1.7690	0.0010
0518	43.420	0.025	10.391	0.005	1.7707	0.0010
0519	43.356	0.025	10.376	0.005	1.7681	0.0010
0520	43.403	0.025	10.387	0.005	1.7700	0.0010
0521	43.361	0.025	10.377	0.005	1.7683	0.0010
0522	43.495	0.025	10.409	0.005	1.7738	0.0010
0523	43.322	0.025	10.368	0.005	1.7667	0.0010
0524	43.300	0.025	10.363	0.005	1.7658	0.0010
0525	43.367	0.025	10.379	0.005	1.7686	0.0010
0526	43.384	0.025	10.383	0.005	1.7693	0.0010
0527	43.416	0.025	10.391	0.005	1.7706	0.0010
0528	43.373	0.025	10.380	0.005	1.7688	0.0010
0529	43.331	0.025	10.370	0.005	1.7671	0.0010
0530	43.523	0.025	10.416	0.005	1.7749	0.0010
0531	43.204	0.025	10.340	0.005	1.7619	0.0010
0532	43.444	0.025	10.397	0.005	1.7717	0.0010
0533	43.336	0.025	10.371	0.005	1.7673	0.0010
0534	43.418	0.025	10.391	0.005	1.7707	0.0010
0535	43.346	0.025	10.374	0.005	1.7677	0.0010
0536	43.348	0.025	10.374	0.005	1.7678	0.0010
0537	42.592	0.025	10.193	0.005	1.7370	0.0010
0538	43.262	0.025	10.354	0.005	1.7643	0.0010
0539	43.394	0.025	10.385	0.005	1.7697	0.0010
0540	43.396	0.025	10.386	0.005	1.7697	0.0010
0541	43.384	0.025	10.383	0.005	1.7693	0.0010
0542	43.331	0.025	10.370	0.005	1.7671	0.0010
0543	43.408	0.025	10.388	0.005	1.7702	0.0010
0544	43.372	0.025	10.380	0.005	1.7688	0.0010
0545	43.331	0.025	10.370	0.005	1.7671	0.0010
0546	43.547	0.025	10.422	0.005	1.7759	0.0010
0547	43.231	0.025	10.346	0.005	1.7630	0.0010
0548	43.454	0.025	10.400	0.005	1.7721	0.0010
0549	43.382	0.025	10.382	0.005	1.7692	0.0010
0550	43.322	0.025	10.368	0.005	1.7667	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0551	42.605	0.025	10.196	0.005	1.7375	0.0010
0552	43.310	0.025	10.365	0.005	1.7662	0.0010
0553	43.327	0.025	10.369	0.005	1.7669	0.0010
0554	43.339	0.025	10.372	0.005	1.7674	0.0010
0555	43.391	0.025	10.384	0.005	1.7695	0.0010
0556	43.387	0.025	10.384	0.005	1.7694	0.0010
0557	43.341	0.025	10.372	0.005	1.7675	0.0010
0558	43.396	0.025	10.386	0.005	1.7697	0.0010
0559	43.415	0.025	10.390	0.005	1.7705	0.0010
0560	43.322	0.025	10.368	0.005	1.7667	0.0010
0561	43.403	0.025	10.387	0.005	1.7700	0.0010
0562	43.361	0.025	10.377	0.005	1.7683	0.0010
0563	43.463	0.025	10.402	0.005	1.7725	0.0010
0564	43.253	0.025	10.352	0.005	1.7639	0.0010
0565	43.415	0.025	10.390	0.005	1.7705	0.0010
0566	43.343	0.025	10.373	0.005	1.7676	0.0010
0567	43.428	0.025	10.393	0.005	1.7711	0.0010
0568	43.385	0.025	10.383	0.005	1.7693	0.0010
0569	43.360	0.025	10.377	0.005	1.7683	0.0010
0570	43.346	0.025	10.374	0.005	1.7677	0.0010
0571	43.367	0.025	10.379	0.005	1.7686	0.0010
0572	43.452	0.025	10.399	0.005	1.7721	0.0010
0573	43.319	0.025	10.367	0.005	1.7666	0.0010
0574	43.399	0.025	10.386	0.005	1.7699	0.0010
0575	43.389	0.025	10.384	0.005	1.7695	0.0010
0576	43.344	0.025	10.373	0.005	1.7676	0.0010
0577	42.652	0.025	10.208	0.005	1.7394	0.0010
0578	43.254	0.025	10.352	0.005	1.7640	0.0010
0579	43.381	0.025	10.382	0.005	1.7691	0.0010
0580	43.370	0.025	10.380	0.005	1.7687	0.0010
0581	43.350	0.025	10.375	0.005	1.7679	0.0010
0582	43.386	0.025	10.383	0.005	1.7693	0.0010
0583	43.290	0.025	10.360	0.005	1.7654	0.0010
0584	43.319	0.025	10.367	0.005	1.7666	0.0010
0585	43.405	0.025	10.388	0.005	1.7701	0.0010
0586	43.351	0.025	10.375	0.005	1.7679	0.0010
0587	43.278	0.025	10.357	0.005	1.7649	0.0010
0588	42.601	0.025	10.195	0.005	1.7373	0.0010
0589	43.303	0.025	10.364	0.005	1.7660	0.0010
0590	43.267	0.025	10.355	0.005	1.7645	0.0010
0591	43.405	0.025	10.388	0.005	1.7701	0.0010
0592	43.453	0.025	10.399	0.005	1.7721	0.0010
0593	43.247	0.025	10.350	0.005	1.7637	0.0010
0594	43.423	0.025	10.392	0.005	1.7709	0.0010
0595	43.278	0.025	10.357	0.005	1.7649	0.0010
0596	42.654	0.025	10.208	0.005	1.7395	0.0010
0597	43.261	0.025	10.353	0.005	1.7642	0.0010
0598	43.324	0.025	10.368	0.005	1.7668	0.0010
0599	43.355	0.025	10.376	0.005	1.7681	0.0010
0600	42.626	0.025	10.201	0.005	1.7384	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0601	43.255	0.025	10.352	0.005	1.7640	0.0010
0602	43.346	0.025	10.374	0.005	1.7677	0.0010
0603	43.411	0.025	10.389	0.005	1.7704	0.0010
0604	43.303	0.025	10.364	0.005	1.7660	0.0010
0605	43.375	0.025	10.381	0.005	1.7689	0.0010
0606	43.372	0.025	10.380	0.005	1.7688	0.0010
0607	43.372	0.025	10.380	0.005	1.7688	0.0010
0608	43.389	0.025	10.384	0.005	1.7695	0.0010
0609	43.331	0.025	10.370	0.005	1.7671	0.0010
0610	43.406	0.025	10.388	0.005	1.7702	0.0010
0611	43.511	0.025	10.413	0.005	1.7744	0.0010
0612	43.312	0.025	10.366	0.005	1.7663	0.0010
0613	43.290	0.025	10.360	0.005	1.7654	0.0010
0614	43.303	0.025	10.364	0.005	1.7660	0.0010
0615	43.365	0.025	10.378	0.005	1.7685	0.0010
0616	43.396	0.025	10.386	0.005	1.7698	0.0010
0617	43.413	0.025	10.390	0.005	1.7705	0.0010
0618	43.237	0.025	10.348	0.005	1.7633	0.0010
0619	42.626	0.025	10.201	0.005	1.7384	0.0010
0620	43.312	0.025	10.366	0.005	1.7663	0.0010
0621	43.393	0.025	10.385	0.005	1.7696	0.0010
0622	43.321	0.025	10.368	0.005	1.7667	0.0010
0623	43.315	0.025	10.366	0.005	1.7665	0.0010
0624	43.437	0.025	10.396	0.005	1.7714	0.0010
0625	43.483	0.025	10.407	0.005	1.7733	0.0010
0626	43.228	0.025	10.345	0.005	1.7629	0.0010
0627	43.456	0.025	10.400	0.005	1.7722	0.0010
0628	43.252	0.025	10.351	0.005	1.7639	0.0010
0629	43.441	0.025	10.396	0.005	1.7716	0.0010
0630	43.327	0.025	10.369	0.005	1.7670	0.0010
0631	43.434	0.025	10.395	0.005	1.7713	0.0010
0632	43.439	0.025	10.396	0.005	1.7715	0.0010
0633	43.283	0.025	10.359	0.005	1.7651	0.0010
0634	43.384	0.025	10.383	0.005	1.7693	0.0010
0635	43.495	0.025	10.409	0.005	1.7738	0.0010
0636	43.391	0.025	10.384	0.005	1.7695	0.0010
0637	43.365	0.025	10.378	0.005	1.7685	0.0010
0638	43.389	0.025	10.384	0.005	1.7695	0.0010
0639	43.314	0.025	10.366	0.005	1.7664	0.0010
0640	43.442	0.025	10.397	0.005	1.7716	0.0010
0641	43.336	0.025	10.371	0.005	1.7673	0.0010
0642	43.413	0.025	10.390	0.005	1.7705	0.0010
0643	43.283	0.025	10.359	0.005	1.7651	0.0010
0644	43.360	0.025	10.377	0.005	1.7683	0.0010
0645	43.425	0.025	10.393	0.005	1.7709	0.0010
0646	43.365	0.025	10.378	0.005	1.7685	0.0010
0647	43.389	0.025	10.384	0.005	1.7695	0.0010
0648	43.274	0.025	10.357	0.005	1.7648	0.0010
0649	43.427	0.025	10.393	0.005	1.7710	0.0010
0650	43.338	0.025	10.372	0.005	1.7674	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0651	43.298	0.025	10.362	0.005	1.7658	0.0010
0652	42.609	0.025	10.197	0.005	1.7377	0.0010
0653	43.298	0.025	10.362	0.005	1.7658	0.0010
0654	43.228	0.025	10.345	0.005	1.7629	0.0010
0655	43.405	0.025	10.388	0.005	1.7701	0.0010
0656	43.429	0.025	10.393	0.005	1.7711	0.0010
0657	43.283	0.025	10.359	0.005	1.7651	0.0010
0658	43.408	0.025	10.389	0.005	1.7702	0.0010
0659	43.387	0.025	10.384	0.005	1.7694	0.0010
0660	43.360	0.025	10.377	0.005	1.7683	0.0010
0661	42.602	0.025	10.196	0.005	1.7374	0.0010
0662	43.393	0.025	10.385	0.005	1.7696	0.0010
0663	43.297	0.025	10.362	0.005	1.7657	0.0010
0664	43.415	0.025	10.390	0.005	1.7705	0.0010
0665	43.386	0.025	10.383	0.005	1.7693	0.0010
0666	43.264	0.025	10.354	0.005	1.7644	0.0010
0667	43.379	0.025	10.382	0.005	1.7691	0.0010
0668	43.473	0.025	10.404	0.005	1.7729	0.0010
0669	43.266	0.025	10.355	0.005	1.7644	0.0010
0670	43.353	0.025	10.375	0.005	1.7680	0.0010
0671	43.485	0.025	10.407	0.005	1.7734	0.0010
0672	43.219	0.025	10.343	0.005	1.7626	0.0010
0673	43.336	0.025	10.371	0.005	1.7673	0.0010
0674	42.760	0.025	10.233	0.005	1.7438	0.0010
0675	43.204	0.025	10.340	0.005	1.7619	0.0010
0676	42.597	0.025	10.194	0.005	1.7372	0.0010
0677	43.267	0.025	10.355	0.005	1.7645	0.0010
0678	43.502	0.025	10.411	0.005	1.7741	0.0010
0679	43.355	0.025	10.376	0.005	1.7681	0.0010
0680	43.332	0.025	10.370	0.005	1.7672	0.0010
0681	43.242	0.025	10.349	0.005	1.7635	0.0010
0682	43.415	0.025	10.390	0.005	1.7705	0.0010
0683	43.427	0.025	10.393	0.005	1.7710	0.0010
0684	43.444	0.025	10.397	0.005	1.7717	0.0010
0685	43.286	0.025	10.359	0.005	1.7653	0.0010
0686	43.456	0.025	10.400	0.005	1.7722	0.0010
0687	43.291	0.025	10.361	0.005	1.7655	0.0010
0688	43.327	0.025	10.369	0.005	1.7670	0.0010
0689	43.355	0.025	10.376	0.005	1.7681	0.0010
0690	42.662	0.025	10.210	0.005	1.7398	0.0010
0691	43.293	0.025	10.361	0.005	1.7656	0.0010
0692	43.365	0.025	10.378	0.005	1.7685	0.0010
0693	43.425	0.025	10.393	0.005	1.7709	0.0010
0694	43.264	0.025	10.354	0.005	1.7644	0.0010
0695	43.449	0.025	10.398	0.005	1.7719	0.0010
0696	43.363	0.025	10.378	0.005	1.7684	0.0010
0697	43.343	0.025	10.373	0.005	1.7676	0.0010
0698	43.447	0.025	10.398	0.005	1.7718	0.0010
0699	43.343	0.025	10.373	0.005	1.7676	0.0010
0700	43.336	0.025	10.371	0.005	1.7673	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0701	43.415	0.025	10.390	0.005	1.7705	0.0010
0702	43.401	0.025	10.387	0.005	1.7700	0.0010
0703	43.454	0.025	10.400	0.005	1.7721	0.0010
0704	43.351	0.025	10.375	0.005	1.7679	0.0010
0705	43.331	0.025	10.370	0.005	1.7671	0.0010
0706	43.242	0.025	10.349	0.005	1.7635	0.0010
0707	42.599	0.025	10.195	0.005	1.7372	0.0010
0708	43.284	0.025	10.359	0.005	1.7652	0.0010
0709	43.384	0.025	10.383	0.005	1.7693	0.0010
0710	43.442	0.025	10.397	0.005	1.7716	0.0010
0711	43.358	0.025	10.377	0.005	1.7682	0.0010
0712	43.310	0.025	10.365	0.005	1.7663	0.0010
0713	43.403	0.025	10.387	0.005	1.7700	0.0010
0714	43.348	0.025	10.374	0.005	1.7678	0.0010
0715	43.430	0.025	10.394	0.005	1.7711	0.0010
0716	43.279	0.025	10.358	0.005	1.7650	0.0010
0717	43.463	0.025	10.402	0.005	1.7725	0.0010
0718	43.296	0.025	10.362	0.005	1.7657	0.0010
0719	43.379	0.025	10.382	0.005	1.7691	0.0010
0720	43.396	0.025	10.386	0.005	1.7698	0.0010
0721	43.231	0.025	10.346	0.005	1.7630	0.0010
0722	43.425	0.025	10.393	0.005	1.7709	0.0010
0723	42.595	0.025	10.194	0.005	1.7371	0.0010
0724	43.199	0.025	10.338	0.005	1.7617	0.0010
0725	43.386	0.025	10.383	0.005	1.7693	0.0010
0726	42.630	0.025	10.202	0.005	1.7385	0.0010
0727	43.207	0.025	10.341	0.005	1.7621	0.0010
0728	43.451	0.025	10.399	0.005	1.7720	0.0010
0729	43.264	0.025	10.354	0.005	1.7644	0.0010
0730	43.303	0.025	10.364	0.005	1.7660	0.0010
0731	42.595	0.025	10.194	0.005	1.7371	0.0010
0732	43.214	0.025	10.342	0.005	1.7623	0.0010
0733	42.705	0.025	10.220	0.005	1.7416	0.0010
0734	43.190	0.025	10.336	0.005	1.7614	0.0010
0735	43.271	0.025	10.356	0.005	1.7646	0.0010
0736	43.480	0.025	10.406	0.005	1.7732	0.0010
0737	42.618	0.025	10.199	0.005	1.7380	0.0010
0738	43.235	0.025	10.347	0.005	1.7632	0.0010
0739	43.399	0.025	10.386	0.005	1.7699	0.0010
0740	43.255	0.025	10.352	0.005	1.7640	0.0010
0741	43.483	0.025	10.407	0.005	1.7733	0.0010
0742	43.255	0.025	10.352	0.005	1.7640	0.0010
0743	42.606	0.025	10.197	0.005	1.7375	0.0010
0744	43.166	0.025	10.331	0.005	1.7604	0.0010
0745	42.609	0.025	10.197	0.005	1.7377	0.0010
0746	43.266	0.025	10.354	0.005	1.7644	0.0010
0747	43.391	0.025	10.384	0.005	1.7695	0.0010
0748	43.452	0.025	10.399	0.005	1.7721	0.0010
0749	43.305	0.025	10.364	0.005	1.7660	0.0010
0750	43.332	0.025	10.370	0.005	1.7672	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0751	43.250	0.025	10.351	0.005	1.7638	0.0010
0752	43.214	0.025	10.342	0.005	1.7623	0.0010
0753	42.636	0.025	10.204	0.005	1.7388	0.0010
0754	43.221	0.025	10.344	0.005	1.7626	0.0010
0755	42.600	0.025	10.195	0.005	1.7373	0.0010
0756	43.163	0.025	10.330	0.005	1.7602	0.0010
0757	43.382	0.025	10.382	0.005	1.7692	0.0010
0758	43.307	0.025	10.364	0.005	1.7661	0.0010
0759	43.231	0.025	10.346	0.005	1.7630	0.0010
0760	42.635	0.025	10.204	0.005	1.7387	0.0010
0761	43.272	0.025	10.356	0.005	1.7647	0.0010
0762	43.399	0.025	10.386	0.005	1.7699	0.0010
0763	43.264	0.025	10.354	0.005	1.7644	0.0010
0764	43.471	0.025	10.404	0.005	1.7728	0.0010
0765	43.122	0.025	10.320	0.005	1.7586	0.0010
0766	43.435	0.025	10.395	0.005	1.7714	0.0010
0767	43.231	0.025	10.346	0.005	1.7630	0.0010
0768	43.422	0.025	10.392	0.005	1.7708	0.0010
0769	43.322	0.025	10.368	0.005	1.7667	0.0010
0770	43.206	0.025	10.340	0.005	1.7620	0.0010
0771	43.267	0.025	10.355	0.005	1.7645	0.0010
0772	42.597	0.025	10.194	0.005	1.7372	0.0010
0773	43.372	0.025	10.380	0.005	1.7688	0.0010
0774	43.353	0.025	10.375	0.005	1.7680	0.0010
0775	43.334	0.025	10.371	0.005	1.7672	0.0010
0776	43.435	0.025	10.395	0.005	1.7714	0.0010
0777	43.134	0.025	10.323	0.005	1.7591	0.0010
0778	42.631	0.025	10.203	0.005	1.7386	0.0010
0779	43.106	0.025	10.316	0.005	1.7579	0.0010
0780	42.660	0.025	10.210	0.005	1.7398	0.0010
0781	43.432	0.025	10.394	0.005	1.7712	0.0010
0782	43.194	0.025	10.337	0.005	1.7615	0.0010
0783	43.454	0.025	10.400	0.005	1.7721	0.0010
0784	43.202	0.025	10.339	0.005	1.7618	0.0010
0785	43.291	0.025	10.361	0.005	1.7655	0.0010
0786	43.387	0.025	10.384	0.005	1.7694	0.0010
0787	43.288	0.025	10.360	0.005	1.7653	0.0010
0788	43.195	0.025	10.338	0.005	1.7616	0.0010
0789	42.630	0.025	10.202	0.005	1.7385	0.0010
0790	43.266	0.025	10.354	0.005	1.7644	0.0010
0791	43.139	0.025	10.324	0.005	1.7593	0.0010
0792	43.343	0.025	10.373	0.005	1.7676	0.0010
0793	43.401	0.025	10.387	0.005	1.7700	0.0010
0794	43.250	0.025	10.351	0.005	1.7638	0.0010
0795	42.618	0.025	10.199	0.005	1.7380	0.0010
0796	43.158	0.025	10.329	0.005	1.7600	0.0010
0797	43.389	0.025	10.384	0.005	1.7695	0.0010
0798	43.276	0.025	10.357	0.005	1.7649	0.0010
0799	43.303	0.025	10.364	0.005	1.7660	0.0010
0800	43.482	0.025	10.406	0.005	1.7732	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0801	43.140	0.025	10.325	0.005	1.7593	0.0010
0802	43.398	0.025	10.386	0.005	1.7698	0.0010
0803	43.187	0.025	10.336	0.005	1.7612	0.0010
0804	42.655	0.025	10.208	0.005	1.7395	0.0010
0805	43.281	0.025	10.358	0.005	1.7651	0.0010
0806	43.091	0.025	10.313	0.005	1.7573	0.0010
0807	43.468	0.025	10.403	0.005	1.7727	0.0010
0808	43.305	0.025	10.364	0.005	1.7660	0.0010
0809	43.332	0.025	10.370	0.005	1.7672	0.0010
0810	43.276	0.025	10.357	0.005	1.7649	0.0010
0811	43.074	0.025	10.309	0.005	1.7566	0.0010
0812	43.449	0.025	10.398	0.005	1.7719	0.0010
0813	43.344	0.025	10.373	0.005	1.7677	0.0010
0814	43.199	0.025	10.338	0.005	1.7617	0.0010
0815	43.380	0.025	10.382	0.005	1.7691	0.0010
0816	43.322	0.025	10.368	0.005	1.7667	0.0010
0817	42.604	0.025	10.196	0.005	1.7374	0.0010
0818	43.135	0.025	10.323	0.005	1.7591	0.0010
0819	43.399	0.025	10.386	0.005	1.7699	0.0010
0820	43.127	0.025	10.321	0.005	1.7588	0.0010
0821	43.281	0.025	10.358	0.005	1.7651	0.0010
0822	43.197	0.025	10.338	0.005	1.7616	0.0010
0823	43.272	0.025	10.356	0.005	1.7647	0.0010
0824	43.442	0.025	10.397	0.005	1.7716	0.0010
0825	43.197	0.025	10.338	0.005	1.7616	0.0010
0826	43.295	0.025	10.361	0.005	1.7656	0.0010
0827	43.317	0.025	10.367	0.005	1.7665	0.0010
0828	43.175	0.025	10.333	0.005	1.7607	0.0010
0829	43.269	0.025	10.355	0.005	1.7646	0.0010
0830	43.271	0.025	10.356	0.005	1.7646	0.0010
0831	42.633	0.025	10.203	0.005	1.7386	0.0010
0832	43.144	0.025	10.325	0.005	1.7595	0.0010
0833	43.475	0.025	10.405	0.005	1.7730	0.0010
0834	43.079	0.025	10.310	0.005	1.7568	0.0010
0835	43.298	0.025	10.362	0.005	1.7658	0.0010
0836	43.423	0.025	10.392	0.005	1.7709	0.0010
0837	43.171	0.025	10.332	0.005	1.7606	0.0010
0838	43.430	0.025	10.394	0.005	1.7711	0.0010
0839	43.298	0.025	10.362	0.005	1.7658	0.0010
0840	43.260	0.025	10.353	0.005	1.7642	0.0010
0841	43.164	0.025	10.330	0.005	1.7603	0.0010
0842	43.221	0.025	10.344	0.005	1.7626	0.0010
0843	43.416	0.025	10.391	0.005	1.7706	0.0010
0844	43.365	0.025	10.378	0.005	1.7685	0.0010
0845	43.137	0.025	10.324	0.005	1.7592	0.0010
0846	43.420	0.025	10.391	0.005	1.7707	0.0010
0847	43.240	0.025	10.348	0.005	1.7634	0.0010
0848	43.194	0.025	10.337	0.005	1.7615	0.0010
0849	43.262	0.025	10.354	0.005	1.7643	0.0010
0850	43.242	0.025	10.349	0.005	1.7635	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0851	43.307	0.025	10.364	0.005	1.7661	0.0010
0852	43.178	0.025	10.334	0.005	1.7609	0.0010
0853	43.346	0.025	10.374	0.005	1.7677	0.0010
0854	43.233	0.025	10.347	0.005	1.7631	0.0010
0855	43.329	0.025	10.370	0.005	1.7670	0.0010
0856	43.188	0.025	10.336	0.005	1.7613	0.0010
0857	43.317	0.025	10.367	0.005	1.7665	0.0010
0858	43.387	0.025	10.384	0.005	1.7694	0.0010
0859	43.158	0.025	10.329	0.005	1.7600	0.0010
0860	43.327	0.025	10.369	0.005	1.7670	0.0010
0861	43.398	0.025	10.386	0.005	1.7698	0.0010
0862	43.151	0.025	10.327	0.005	1.7598	0.0010
0863	43.240	0.025	10.348	0.005	1.7634	0.0010
0864	43.231	0.025	10.346	0.005	1.7630	0.0010
0865	42.595	0.025	10.194	0.005	1.7371	0.0010
0866	43.269	0.025	10.355	0.005	1.7646	0.0010
0867	43.195	0.025	10.338	0.005	1.7616	0.0010
0868	43.338	0.025	10.372	0.005	1.7674	0.0010
0869	43.183	0.025	10.335	0.005	1.7611	0.0010
0870	43.362	0.025	10.377	0.005	1.7684	0.0010
0871	43.250	0.025	10.351	0.005	1.7638	0.0010
0872	43.391	0.025	10.384	0.005	1.7695	0.0010
0873	43.410	0.025	10.389	0.005	1.7703	0.0010
0874	43.075	0.025	10.309	0.005	1.7567	0.0010
0875	43.290	0.025	10.360	0.005	1.7654	0.0010
0876	43.207	0.025	10.341	0.005	1.7621	0.0010
0877	43.458	0.025	10.400	0.005	1.7723	0.0010
0878	43.154	0.025	10.328	0.005	1.7599	0.0010
0879	43.333	0.025	10.371	0.005	1.7672	0.0010
0880	43.295	0.025	10.361	0.005	1.7656	0.0010
0881	43.139	0.025	10.324	0.005	1.7593	0.0010
0882	43.192	0.025	10.337	0.005	1.7614	0.0010
0883	43.322	0.025	10.368	0.005	1.7667	0.0010
0884	43.401	0.025	10.387	0.005	1.7700	0.0010
0885	43.218	0.025	10.343	0.005	1.7625	0.0010
0886	43.279	0.025	10.358	0.005	1.7650	0.0010
0887	43.074	0.025	10.309	0.005	1.7566	0.0010
0888	43.377	0.025	10.381	0.005	1.7690	0.0010
0889	43.202	0.025	10.339	0.005	1.7619	0.0010
0890	43.317	0.025	10.367	0.005	1.7665	0.0010
0891	43.199	0.025	10.339	0.005	1.7617	0.0010
0892	43.235	0.025	10.347	0.005	1.7632	0.0010
0893	43.151	0.025	10.327	0.005	1.7598	0.0010
0894	43.375	0.025	10.381	0.005	1.7689	0.0010
0895	43.252	0.025	10.351	0.005	1.7639	0.0010
0896	43.230	0.025	10.346	0.005	1.7630	0.0010
0897	43.341	0.025	10.373	0.005	1.7675	0.0010
0898	43.194	0.025	10.337	0.005	1.7615	0.0010
0899	43.182	0.025	10.334	0.005	1.7610	0.0010
0900	43.348	0.025	10.374	0.005	1.7678	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0901	43.243	0.025	10.349	0.005	1.7635	0.0010
0902	43.075	0.025	10.309	0.005	1.7567	0.0010
0903	43.389	0.025	10.384	0.005	1.7695	0.0010
0904	43.329	0.025	10.370	0.005	1.7670	0.0010
0905	43.146	0.025	10.326	0.005	1.7595	0.0010
0906	43.089	0.025	10.312	0.005	1.7572	0.0010
0907	43.295	0.025	10.361	0.005	1.7656	0.0010
0908	43.238	0.025	10.348	0.005	1.7633	0.0010
0909	43.266	0.025	10.355	0.005	1.7644	0.0010
0910	43.434	0.025	10.395	0.005	1.7713	0.0010
0911	43.055	0.025	10.304	0.005	1.7558	0.0010
0912	43.218	0.025	10.343	0.005	1.7625	0.0010
0913	43.303	0.025	10.364	0.005	1.7660	0.0010
0914	43.358	0.025	10.377	0.005	1.7682	0.0010
0915	43.231	0.025	10.346	0.005	1.7630	0.0010
0916	43.363	0.025	10.378	0.005	1.7684	0.0010
0917	43.014	0.025	10.294	0.005	1.7542	0.0010
0918	43.267	0.025	10.355	0.005	1.7645	0.0010
0919	43.254	0.025	10.352	0.005	1.7640	0.0010
0920	43.259	0.025	10.353	0.005	1.7642	0.0010
0921	43.254	0.025	10.352	0.005	1.7640	0.0010
0922	43.303	0.025	10.364	0.005	1.7660	0.0010
0923	43.283	0.025	10.359	0.005	1.7651	0.0010
0924	43.276	0.025	10.357	0.005	1.7649	0.0010
0925	43.264	0.025	10.354	0.005	1.7644	0.0010
0926	43.058	0.025	10.305	0.005	1.7560	0.0010
0927	43.266	0.025	10.355	0.005	1.7644	0.0010
0928	43.255	0.025	10.352	0.005	1.7640	0.0010
0929	43.233	0.025	10.347	0.005	1.7631	0.0010
0930	43.231	0.025	10.346	0.005	1.7630	0.0010
0931	43.231	0.025	10.346	0.005	1.7630	0.0010
0932	43.266	0.025	10.355	0.005	1.7644	0.0010
0933	43.269	0.025	10.355	0.005	1.7646	0.0010
0934	43.341	0.025	10.373	0.005	1.7675	0.0010
0935	43.170	0.025	10.332	0.005	1.7605	0.0010
0936	43.185	0.025	10.335	0.005	1.7612	0.0010
0937	43.350	0.025	10.375	0.005	1.7679	0.0010
0938	43.082	0.025	10.311	0.005	1.7570	0.0010
0939	43.249	0.025	10.350	0.005	1.7637	0.0010
0940	43.459	0.025	10.401	0.005	1.7723	0.0010
0941	42.985	0.025	10.287	0.005	1.7530	0.0010
0942	43.267	0.025	10.355	0.005	1.7645	0.0010
0943	43.257	0.025	10.352	0.005	1.7641	0.0010
0944	43.209	0.025	10.341	0.005	1.7621	0.0010
0945	43.425	0.025	10.393	0.005	1.7709	0.0010
0946	43.027	0.025	10.297	0.005	1.7547	0.0010
0947	43.278	0.025	10.357	0.005	1.7649	0.0010
0948	43.405	0.025	10.388	0.005	1.7701	0.0010
0949	43.038	0.025	10.300	0.005	1.7551	0.0010
0950	43.226	0.025	10.345	0.005	1.7628	0.0010

Vial No	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
0951	43.389	0.025	10.384	0.005	1.7695	0.0010
0952	43.221	0.025	10.344	0.005	1.7626	0.0010
0953	43.153	0.025	10.327	0.005	1.7598	0.0010
0954	43.329	0.025	10.370	0.005	1.7670	0.0010
0955	43.053	0.025	10.304	0.005	1.7558	0.0010
0956	43.235	0.025	10.347	0.005	1.7632	0.0010
0957	43.194	0.025	10.337	0.005	1.7615	0.0010
0958	43.298	0.025	10.362	0.005	1.7658	0.0010
0959	43.279	0.025	10.358	0.005	1.7650	0.0010
0960	43.182	0.025	10.334	0.005	1.7610	0.0010
0961	43.195	0.025	10.338	0.005	1.7616	0.0010
0962	43.408	0.025	10.389	0.005	1.7702	0.0010
0963	43.170	0.025	10.332	0.005	1.7605	0.0010
0964	43.286	0.025	10.359	0.005	1.7653	0.0010
0965	43.249	0.025	10.350	0.005	1.7637	0.0010
0966	43.082	0.025	10.311	0.005	1.7570	0.0010
0967	43.213	0.025	10.342	0.005	1.7623	0.0010
0968	43.432	0.025	10.394	0.005	1.7712	0.0010
0969	43.072	0.025	10.308	0.005	1.7565	0.0010
0970	43.286	0.025	10.359	0.005	1.7653	0.0010
0971	43.341	0.025	10.373	0.005	1.7675	0.0010
0972	43.156	0.025	10.328	0.005	1.7600	0.0010
0973	43.132	0.025	10.323	0.005	1.7590	0.0010
0974	43.281	0.025	10.358	0.005	1.7651	0.0010
0975	43.338	0.025	10.372	0.005	1.7674	0.0010
0976	43.039	0.025	10.300	0.005	1.7552	0.0010
0977	43.303	0.025	10.364	0.005	1.7660	0.0010
0978	43.168	0.025	10.331	0.005	1.7605	0.0010
0979	43.223	0.025	10.344	0.005	1.7627	0.0010
0980	43.276	0.025	10.357	0.005	1.7649	0.0010
0981	43.168	0.025	10.331	0.005	1.7605	0.0010
0982	43.233	0.025	10.347	0.005	1.7631	0.0010
0983	43.230	0.025	10.346	0.005	1.7630	0.0010
0984	43.257	0.025	10.352	0.005	1.7641	0.0010
0985	43.393	0.025	10.385	0.005	1.7696	0.0010
0986	43.195	0.025	10.338	0.005	1.7616	0.0010
0987	43.077	0.025	10.309	0.005	1.7568	0.0010
0988	43.225	0.025	10.345	0.005	1.7628	0.0010
0989	43.266	0.025	10.355	0.005	1.7644	0.0010
0990	43.175	0.025	10.333	0.005	1.7607	0.0010
0991	43.310	0.025	10.365	0.005	1.7663	0.0010
0992	43.271	0.025	10.356	0.005	1.7647	0.0010
0993	43.123	0.025	10.320	0.005	1.7586	0.0010
0994	43.451	0.025	10.399	0.005	1.7720	0.0010
0995	43.062	0.025	10.306	0.005	1.7561	0.0010
0996	43.141	0.025	10.325	0.005	1.7593	0.0010
0997	43.291	0.025	10.361	0.005	1.7655	0.0010
0998	43.281	0.025	10.358	0.005	1.7651	0.0010
0999	43.048	0.025	10.302	0.005	1.7556	0.0010
1000	43.370	0.025	10.380	0.005	1.7687	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
1001	43.194	0.025	10.337	0.005	1.7615	0.0010
1002	43.046	0.025	10.302	0.005	1.7555	0.0010
1003	43.382	0.025	10.382	0.005	1.7692	0.0010
1004	43.070	0.025	10.308	0.005	1.7565	0.0010
1005	43.245	0.025	10.350	0.005	1.7636	0.0010
1006	43.168	0.025	10.331	0.005	1.7605	0.0010
1007	43.439	0.025	10.396	0.005	1.7715	0.0010
1008	43.026	0.025	10.297	0.005	1.7547	0.0010
1009	43.393	0.025	10.385	0.005	1.7696	0.0010
1010	43.235	0.025	10.347	0.005	1.7632	0.0010
1011	43.014	0.025	10.294	0.005	1.7542	0.0010
1012	43.238	0.025	10.348	0.005	1.7633	0.0010
1013	43.384	0.025	10.383	0.005	1.7693	0.0010
1014	43.255	0.025	10.352	0.005	1.7640	0.0010
1015	43.161	0.025	10.329	0.005	1.7602	0.0010
1016	43.225	0.025	10.345	0.005	1.7628	0.0010
1017	43.087	0.025	10.312	0.005	1.7572	0.0010
1018	43.194	0.025	10.337	0.005	1.7615	0.0010
1019	43.189	0.025	10.336	0.005	1.7613	0.0010
1020	43.358	0.025	10.377	0.005	1.7682	0.0010
1021	43.129	0.025	10.322	0.005	1.7588	0.0010
1022	43.115	0.025	10.318	0.005	1.7583	0.0010
1023	43.235	0.025	10.347	0.005	1.7632	0.0010
1024	43.348	0.025	10.374	0.005	1.7678	0.0010
1025	43.142	0.025	10.325	0.005	1.7594	0.0010
1026	43.218	0.025	10.343	0.005	1.7625	0.0010
1027	43.314	0.025	10.366	0.005	1.7664	0.0010
1028	43.137	0.025	10.324	0.005	1.7592	0.0010
1029	43.259	0.025	10.353	0.005	1.7642	0.0010
1030	43.137	0.025	10.324	0.005	1.7592	0.0010
1031	43.147	0.025	10.326	0.005	1.7596	0.0010
1032	43.389	0.025	10.384	0.005	1.7695	0.0010
1033	43.165	0.025	10.330	0.005	1.7603	0.0010
1034	43.125	0.025	10.321	0.005	1.7587	0.0010
1035	43.182	0.025	10.334	0.005	1.7610	0.0010
1036	43.230	0.025	10.346	0.005	1.7630	0.0010
1037	43.298	0.025	10.362	0.005	1.7658	0.0010
1038	43.094	0.025	10.313	0.005	1.7575	0.0010
1039	43.207	0.025	10.341	0.005	1.7621	0.0010
1040	43.266	0.025	10.355	0.005	1.7644	0.0010
1041	43.113	0.025	10.318	0.005	1.7582	0.0010
1042	43.298	0.025	10.362	0.005	1.7658	0.0010
1043	43.333	0.025	10.371	0.005	1.7672	0.0010
1044	43.069	0.025	10.307	0.005	1.7564	0.0010
1045	43.312	0.025	10.366	0.005	1.7663	0.0010
1046	43.182	0.025	10.334	0.005	1.7610	0.0010
1047	43.074	0.025	10.309	0.005	1.7566	0.0010
1048	43.250	0.025	10.351	0.005	1.7638	0.0010
1049	43.178	0.025	10.334	0.005	1.7609	0.0010
1050	43.300	0.025	10.363	0.005	1.7658	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
1051	43.295	0.025	10.361	0.005	1.7656	0.0010
1052	43.075	0.025	10.309	0.005	1.7567	0.0010
1053	43.303	0.025	10.364	0.005	1.7660	0.0010
1054	43.243	0.025	10.349	0.005	1.7635	0.0010
1055	43.111	0.025	10.318	0.005	1.7581	0.0010
1056	43.110	0.025	10.317	0.005	1.7581	0.0010
1057	43.312	0.025	10.366	0.005	1.7663	0.0010
1058	43.105	0.025	10.316	0.005	1.7579	0.0010
1059	43.389	0.025	10.384	0.005	1.7695	0.0010
1060	43.262	0.025	10.354	0.005	1.7643	0.0010
1061	43.033	0.025	10.299	0.005	1.7549	0.0010
1062	43.240	0.025	10.348	0.005	1.7634	0.0010
1063	43.194	0.025	10.337	0.005	1.7615	0.0010
1064	43.244	0.025	10.349	0.005	1.7635	0.0010
1065	43.312	0.025	10.366	0.005	1.7663	0.0010
1066	43.129	0.025	10.322	0.005	1.7589	0.0010
1067	43.247	0.025	10.350	0.005	1.7637	0.0010
1068	43.365	0.025	10.378	0.005	1.7685	0.0010
1069	43.184	0.025	10.335	0.005	1.7611	0.0010
1070	43.190	0.025	10.336	0.005	1.7614	0.0010
1071	43.113	0.025	10.318	0.005	1.7582	0.0010
1072	43.316	0.025	10.366	0.005	1.7665	0.0010
1073	43.173	0.025	10.332	0.005	1.7607	0.0010
1074	43.338	0.025	10.372	0.005	1.7674	0.0010
1075	43.012	0.025	10.294	0.005	1.7541	0.0010
1076	43.424	0.025	10.392	0.005	1.7709	0.0010
1077	42.990	0.025	10.288	0.005	1.7532	0.0010
1078	43.170	0.025	10.332	0.005	1.7605	0.0010
1079	43.187	0.025	10.336	0.005	1.7612	0.0010
1080	43.161	0.025	10.330	0.005	1.7602	0.0010
1081	43.206	0.025	10.340	0.005	1.7620	0.0010
1082	43.468	0.025	10.403	0.005	1.7727	0.0010
1083	43.009	0.025	10.293	0.005	1.7540	0.0010
1084	43.148	0.025	10.326	0.005	1.7596	0.0010
1085	43.372	0.025	10.380	0.005	1.7688	0.0010
1086	43.033	0.025	10.299	0.005	1.7549	0.0010
1087	43.166	0.025	10.331	0.005	1.7604	0.0010
1088	43.369	0.025	10.379	0.005	1.7686	0.0010
1089	43.118	0.025	10.319	0.005	1.7584	0.0010
1090	43.065	0.025	10.307	0.005	1.7563	0.0010
1091	43.216	0.025	10.343	0.005	1.7624	0.0010
1092	43.316	0.025	10.366	0.005	1.7665	0.0010
1093	43.026	0.025	10.297	0.005	1.7547	0.0010
1094	43.230	0.025	10.346	0.005	1.7630	0.0010
1095	43.262	0.025	10.354	0.005	1.7643	0.0010
1096	43.208	0.025	10.341	0.005	1.7621	0.0010
1097	43.094	0.025	10.314	0.005	1.7575	0.0010
1098	43.194	0.025	10.337	0.005	1.7615	0.0010
1099	43.317	0.025	10.367	0.005	1.7665	0.0010
1100	43.244	0.025	10.349	0.005	1.7635	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
1101	43.166	0.025	10.331	0.005	1.7604	0.0010
1102	43.178	0.025	10.334	0.005	1.7609	0.0010
1103	43.310	0.025	10.365	0.005	1.7663	0.0010
1104	43.033	0.025	10.299	0.005	1.7549	0.0010
1105	43.238	0.025	10.348	0.005	1.7633	0.0010
1106	43.285	0.025	10.359	0.005	1.7652	0.0010
1107	43.060	0.025	10.305	0.005	1.7561	0.0010
1108	43.202	0.025	10.339	0.005	1.7619	0.0010
1109	43.377	0.025	10.381	0.005	1.7690	0.0010
1110	43.161	0.025	10.330	0.005	1.7602	0.0010
1111	43.230	0.025	10.346	0.005	1.7630	0.0010
1112	43.177	0.025	10.333	0.005	1.7608	0.0010
1113	43.156	0.025	10.328	0.005	1.7600	0.0010
1114	43.362	0.025	10.378	0.005	1.7684	0.0010
1115	43.120	0.025	10.320	0.005	1.7585	0.0010
1116	43.269	0.025	10.355	0.005	1.7646	0.0010
1117	43.283	0.025	10.359	0.005	1.7651	0.0010
1118	43.007	0.025	10.293	0.005	1.7539	0.0010
1119	43.434	0.025	10.395	0.005	1.7713	0.0010
1120	43.096	0.025	10.314	0.005	1.7575	0.0010
1121	43.118	0.025	10.319	0.005	1.7584	0.0010
1122	43.388	0.025	10.384	0.005	1.7694	0.0010
1123	43.221	0.025	10.344	0.005	1.7626	0.0010
1124	43.154	0.025	10.328	0.005	1.7599	0.0010
1125	43.034	0.025	10.299	0.005	1.7550	0.0010
1126	43.307	0.025	10.364	0.005	1.7661	0.0010
1127	43.391	0.025	10.384	0.005	1.7695	0.0010
1128	43.033	0.025	10.299	0.005	1.7549	0.0010
1129	43.379	0.025	10.382	0.005	1.7691	0.0010
1130	43.034	0.025	10.299	0.005	1.7550	0.0010
1131	43.204	0.025	10.340	0.005	1.7619	0.0010
1132	43.340	0.025	10.372	0.005	1.7675	0.0010
1133	43.089	0.025	10.312	0.005	1.7572	0.0010
1134	43.190	0.025	10.336	0.005	1.7614	0.0010
1135	43.225	0.025	10.345	0.005	1.7628	0.0010
1136	43.307	0.025	10.364	0.005	1.7661	0.0010
1137	43.201	0.025	10.339	0.005	1.7618	0.0010
1138	43.091	0.025	10.313	0.005	1.7573	0.0010
1139	43.319	0.025	10.367	0.005	1.7666	0.0010
1140	43.213	0.025	10.342	0.005	1.7623	0.0010
1141	43.055	0.025	10.304	0.005	1.7558	0.0010
1142	43.182	0.025	10.334	0.005	1.7610	0.0010
1143	43.269	0.025	10.355	0.005	1.7646	0.0010
1144	43.235	0.025	10.347	0.005	1.7632	0.0010
1145	43.127	0.025	10.321	0.005	1.7588	0.0010
1146	43.377	0.025	10.381	0.005	1.7690	0.0010
1147	43.166	0.025	10.331	0.005	1.7604	0.0010
1148	43.242	0.025	10.349	0.005	1.7635	0.0010
1149	43.072	0.025	10.308	0.005	1.7565	0.0010
1150	43.136	0.025	10.323	0.005	1.7591	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
1151	43.374	0.025	10.380	0.005	1.7688	0.0010
1152	43.024	0.025	10.297	0.005	1.7546	0.0010
1153	43.264	0.025	10.354	0.005	1.7644	0.0010
1154	43.119	0.025	10.319	0.005	1.7584	0.0010
1155	43.323	0.025	10.368	0.005	1.7668	0.0010
1156	43.158	0.025	10.329	0.005	1.7601	0.0010
1157	43.342	0.025	10.373	0.005	1.7675	0.0010
1158	43.126	0.025	10.321	0.005	1.7587	0.0010
1159	43.282	0.025	10.358	0.005	1.7651	0.0010
1160	43.228	0.025	10.346	0.005	1.7629	0.0010
1161	43.156	0.025	10.328	0.005	1.7600	0.0010
1162	43.208	0.025	10.341	0.005	1.7621	0.0010
1163	43.187	0.025	10.336	0.005	1.7612	0.0010
1164	43.312	0.025	10.366	0.005	1.7663	0.0010
1165	43.132	0.025	10.323	0.005	1.7590	0.0010
1166	43.167	0.025	10.331	0.005	1.7604	0.0010
1167	43.316	0.025	10.367	0.005	1.7665	0.0010
1168	43.182	0.025	10.335	0.005	1.7610	0.0010
1169	43.144	0.025	10.325	0.005	1.7595	0.0010
1170	43.323	0.025	10.368	0.005	1.7668	0.0010
1171	43.340	0.025	10.372	0.005	1.7675	0.0010
1172	43.038	0.025	10.300	0.005	1.7552	0.0010
1173	43.191	0.025	10.337	0.005	1.7614	0.0010
1174	43.232	0.025	10.346	0.005	1.7631	0.0010
1175	43.203	0.025	10.339	0.005	1.7619	0.0010
1176	43.117	0.025	10.319	0.005	1.7584	0.0010
1177	43.299	0.025	10.362	0.005	1.7658	0.0010
1178	43.186	0.025	10.335	0.005	1.7612	0.0010
1179	43.240	0.025	10.348	0.005	1.7634	0.0010
1180	43.220	0.025	10.344	0.005	1.7626	0.0010
1181	43.139	0.025	10.324	0.005	1.7593	0.0010
1182	43.139	0.025	10.324	0.005	1.7593	0.0010
1183	43.254	0.025	10.352	0.005	1.7640	0.0010
1184	43.206	0.025	10.340	0.005	1.7620	0.0010
1185	43.187	0.025	10.336	0.005	1.7612	0.0010
1186	43.057	0.025	10.305	0.005	1.7559	0.0010
1187	43.198	0.025	10.338	0.005	1.7617	0.0010
1188	43.326	0.025	10.369	0.005	1.7669	0.0010
1189	43.122	0.025	10.320	0.005	1.7586	0.0010
1190	43.323	0.025	10.368	0.005	1.7668	0.0010
1191	43.120	0.025	10.320	0.005	1.7585	0.0010
1192	43.175	0.025	10.333	0.005	1.7608	0.0010
1193	43.072	0.025	10.308	0.005	1.7566	0.0010
1194	43.336	0.025	10.371	0.005	1.7673	0.0010
1195	43.018	0.025	10.295	0.005	1.7543	0.0010
1196	43.311	0.025	10.365	0.005	1.7663	0.0010
1197	43.186	0.025	10.335	0.005	1.7612	0.0010
1198	43.103	0.025	10.316	0.005	1.7578	0.0010
1199	43.290	0.025	10.360	0.005	1.7654	0.0010
1200	43.211	0.025	10.341	0.005	1.7622	0.0010

	^{238}U		^{235}U		^{239}Pu	
Vial No	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
1201	43.093	0.025	10.313	0.005	1.7574	0.0010
1202	43.182	0.025	10.335	0.005	1.7610	0.0010
1203	43.091	0.025	10.313	0.005	1.7573	0.0010
1204	43.386	0.025	10.383	0.005	1.7694	0.0010
1205	43.160	0.025	10.329	0.005	1.7601	0.0010
1208	43.203	0.025	10.339	0.005	1.7619	0.0010
1207	43.107	0.025	10.316	0.005	1.7580	0.0010
1206	43.312	0.025	10.366	0.005	1.7663	0.0010
1209	43.115	0.025	10.319	0.005	1.7583	0.0010
1210	43.204	0.025	10.340	0.005	1.7619	0.0010
1211	43.213	0.025	10.342	0.005	1.7623	0.0010
1212	43.256	0.025	10.352	0.005	1.7640	0.0010
1213	43.223	0.025	10.344	0.005	1.7627	0.0010
1214	43.450	0.025	10.399	0.005	1.7719	0.0010
1215	42.946	0.025	10.278	0.005	1.7514	0.0010

[1] The certified values are traceable to the values on the respective metal certificates (EC NRM 101, NBL CRM-116 and CETAMA MP2).
[2] The certified uncertainty is the expanded uncertainty with a coverage factor $k = 2$ corresponding to a level of confidence of about 95 % estimated in accordance with ISO/IEC Guide 98-3, Guide to the Expression of Uncertainty in Measurement (GUM:1995), ISO, 2008.

Annex 2: The certificate of EC NRM 101 uranium metal

Certified Nuclear Reference Material

Certificate of Analysis

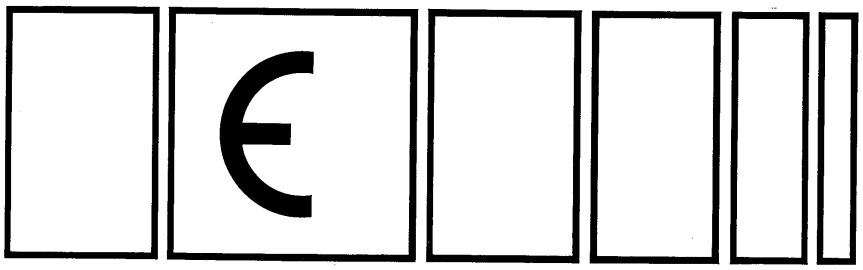
EC NUCLEAR REFERENCE MATERIAL NO. 101

MATERIAL : URANIUM METAL

URANIUM MASS FRACTION : (999.85 ± 0.05) g·kg-1

The uncertainty has been calculated by multiplying the estimated overall standard deviation by a factor of two. This corresponds to a confidence level of about 95 percent.

Commission of the European Communities
Joint Research Centre
Geel Establishment (CBNM)



Annex 3: The certificate of NBL CRM-116 uranium metal

U. S. Department of Energy
New Brunswick Laboratory

New Brunswick Laboratory
Certified Reference Materials
Certificate of Analysis

CRM 116

Uranium (Enriched) Metal
(Uranium and Uranium-235 Standard)

Uranium (etched metal basis) ..... $99.967_2 \pm 0.006_9$ Wt.%
($\alpha = 0.05$, n = 6)

Uranium-235 ..... $93.121_5 \pm 0.004_7$ Wt.%
($\alpha = 0.05$, n = 6)
$93.183_7 \pm 0.004_7$ At.%

Relative atomic weight 235.201

Metal must be etched in 1 + 1 HNO_3, rinsed in distilled-deionized water and acetone, and dried prior to use.

REFERENCE METHODS OF ANALYSIS: Titrimetry (high precision NBL method) verified with NBL CRM 112-A Uranium Metal Standard and thermal ionization mass spectrometry verified with NBL CRM U930 Uranium Isotopic Standard.

June 1978
Argonne, Illinois

Carleton D. Bingham
Director

Annex 4: The certificate of CETAMA MP2 plutonium metal

CETAMA

COMMISSARIAT A L'ENERGIE ATOMIQUE

COMMISSION D'ETABLISSEMENT DES METHODES D'ANALYSE

cea

REFERENCE MATERIAL CERTIFICATE

PLUTONIUM METAL
"MP2"

Sample n° Xxxx Mass : 0.xxxxxx ± 0.000012 g

(For X and x values see list page 4)

The reference material to which this certificate relates is intended for the calibration of chemical composition measurement. The overall chemical content of plutonium is certified. The confidence interval associated with the certified value for a single sample, takes into account uncertainties associated to with analysis and heteregenity of metal. This content, expressed as a percentage of mass, was the following on 12 march 2001 for a single sample with a probability level of 0.95.

99.90 ± 0.04 %

THE TRUE MASS OF THE SAMPLE A ± **12 µg**, RELATED TO A VACUUM, IS THAT INDICATED IN THIS CERTIFICATE AND ON THE AMPOULE.

The possibility of surface oxidation makes it impossible to envisage weighing at the time of use

Isotopique composition is certified on 12 march 2001 : see certificate IRMM page3

The preparation, analysis and certification of the plutonium to which this certificate relates was carried out by different units of the CEA group under the supervision of the Committee for Establishing Analysis Methods (CETAMA).

CETAMA CRM manager

CETAMA
CEA VALRHO Marcoule
30207 BAGNOLS SUR CEZE CEDEX
Téléphone 04.66.79.69.88 - Télécopie 04.66.79.69.89

ISO 9001 BUREAU VERITAS Certification

On 12/03/2001, the metal contained around:

- by weight, 489 $mg.kg^{-1}$ of uranium,
- by weight, 438 $mg.kg^{-1}$ of américium..

UTILISATION

The sample, which consists of a piece of metal, is supplied in a double glass ampoule filled with pure nitrogen at a pressure of around 0.1 Pascal.

The ampoule must be opened with care inside a glove box. All the sample must be transferred to the dissolver.

Cover with 0.1 $mol.l^{-1}$ hydrochloric acid. The ampoule must be thoroughly washed with the same acid to recover any particles of metal which may have become separated. In 2 ml fractions, add the necessary quantity of 12 $mol.l^{-1}$ hydrochloric acid of guaranteed purity to obtain a 4 $mol.l^{-1}$ hydrochloric acid solution. Allow dissolving to proceed without heating for 10 to 15 minutes, then heat to boiling point. If there are still particles of plutonium at the bottom of the dissolver after heating for two hours, add 2 ml of 12 $mol.l^{-1}$ hydrochloric acid and 2 drops of 1 $mol.l^{-1}$ hydrofluoric acid and continue heating for another two hours. Repeat the operation if necessary until the material is totally dissolved.
If plutonium fluoride precipitates out, add a few drops of aluminium nitrate (approximately one $mol.l^{-1}$)..
Allow to cool and adjust to the required volume.

ADDITIONAL INFORMATION

The certified plutonium content has been deduced from analysis of impurities carried out by five laboratories and checked by chemical assay of the plutonium in two different laboratories using three different methods of analysis.
Spark Source Mass Spectrometry has given a full analysis of the impurities and, where concentration levels allowed, inductively-coupled plasma atomic emission spectrometry has been used to establish the concentrations of some of them.
The uranium was determined by laser spectrofluorimetry and the americium by gamma spectrometry.Carbon was determined by coulometry, after transformation into gaseous form by combustion in oxygen.
The gases were analysed by chromatography in the aqueous phase:
- for nitrogen and oxygen after extraction by high temperature stream under an inert gas,
- for hydrogen after diffusion in a vacuum.

CETAMA
CEA VALRHO Marcoule
30207 BAGNOLS SUR CEZE CEDEX
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IRMM

Institute for Reference Materials and Measurements

CERTIFICATE OF ISOTOPIC COMPOSITION

Geel, 30 May 2001

1. Applicant: Mr G. Lamarque
   Président de la Cetama

2. Sample Identification: MP2 (Pu metal)

3. Isotopic composition:

isotope amount ratio(s)	
$n(^{238}Pu)/n(^{239}Pu)$	0.000 033 15(41)
$n(^{240}Pu)/n(^{239}Pu)$	0.022 437 4(99)
$n(^{241}Pu)/n(^{239}Pu)$	0.000 298 0(17)
$n(^{242}Pu)/n(^{239}Pu)$	0.000 070 87(71)

amount fraction (·100)		mass fraction (·100)	
$n(^{238}Pu)/n(Pu)$	0.003 241(40)	$m(^{238}Pu)/m(Pu)$	0.003 227(40)
$n(^{239}Pu)/n(Pu)$	97.767 05(98)	$m(^{239}Pu)/m(Pu)$	97.757 76(98)
$n(^{240}Pu)/n(Pu)$	2.193 64(94)	$m(^{240}Pu)/m(Pu)$	2.202 62(95)
$n(^{241}Pu)/n(Pu)$	0.029 14(17)	$m(^{241}Pu)/m(Pu)$	0.029 38(17)
$n(^{242}Pu)/n(Pu)$	0.006 929(69)	$m(^{242}Pu)/m(Pu)$	0.007 015(70)

molar mass: 239.074 888(11) $g \cdot mol^{-1}$

4. Reference number: IMN 10031

5. Remarks:

The above values are valid for 12 March 2001. All uncertainties indicated are expanded uncertainties $U = k \cdot u_c$ where u_c is the combined standard uncertainty calculated according to the ISO/BIPM guide. The uncertainties are given in parentheses and include a coverage factor $k=2$. They apply to the last two digits of the value. The values certified are traceable to the SI.
The primary certified values are the isotope amount ratios; other values are derived from them. Reproducing the derived values may result in differences due to rounding errors.
Mass spectrometric measurements were performed by A Verbruggen and F Kehoe by TIMS on samples chemically prepared by F Kehoe. A Verbruggen was responsible for the preparation and issuance of the certificate.

A Verbruggen
Isotope Measurements Unit

Copy: R Wellum
F Kehoe

B-2440 GEEL (Belgium)
Tel. +32-14-571 608 - Fax +32-14-571 883

European Commission - JRC

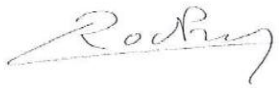
30207 BAGNOLS SUR CEZE CEDEX
Téléphone 04.66.79.69.88 - Télécopie 04.66.79.69.89

Packaging list for IRMM

The numbers of the ingots and the associated masses are as follows:

Ingot number	Mass (g)
A934	0.587859
A949	0.430987
A952	0.567216
A968	0.434526
A975	0.510770
C321	0.640299
C569	0.592943
C581	0.632827
A123	0.414082
A174	0.602206
A307	0.434852
A314	0.561821
A345	0.514834
A451	0.436194
A518	0.624022
A662	0.469822
A035	0.479086
A453	0.598728
A455	0.563210

CETAMA CRM manager



CETAMA
CEA VALRHO Marcoule
30207 BAGNOLS SUR CEZE CEDEX
Téléphone 04.66.79.69.88 - Télécopie 04.66.79.69.89

Annex 5: The certificate of isotopic abundances of CETAMA MP2 by IRMM

EUROPEAN COMMISSION
DIRECTORATE GENERAL JRC
JOINT RESEARCH CENTRE
IRMM
Institute for Reference Materials and Measurements

CERTIFICATE of a reference measurement

IM/MeaC/07/116

11 April 2007

SUBJECT : Recertification of CEA CETAMA MP2

1. Applicant: A. Verbruggen

2. Sample Identification:
   - CEA/CETAMA/MP2
   - Chemical form: Pu metal provided by CEA/CETAMA

3. Measurands:
   - Isotopic composition

isotope amount ratio(s)	
$n(^{238}Pu)/\ n(^{239}Pu)$	0.000 030 83(29)
$n(^{240}Pu)/\ n(^{239}Pu)$	0.022 432 4(51)
$n(^{241}Pu)/\ n(^{239}Pu)$	0.000 237 8(31)
$n(^{242}Pu)/\ n(^{239}Pu)$	0.000 075 70(78)

amount fraction (·100)		mass fraction (·100)	
$n(^{238}Pu)/n(Pu)$	0.003 015(29)	$m(^{238}Pu)/m(Pu)$	0.003 002(28)
$n(^{239}Pu)/n(Pu)$	97.773 05(58)	$m(^{239}Pu)/m(Pu)$	97.763 80(59)
$n(^{240}Pu)/n(Pu)$	2.193 28(49)	$m(^{240}Pu)/m(Pu)$	2.202 27(49)
$n(^{241}Pu)/n(Pu)$	0.023 25(30)	$m(^{241}Pu)/m(Pu)$	0.023 44(31)
$n(^{242}Pu)/n(Pu)$	0.007 402(76)	$m(^{242}Pu)/m(Pu)$	0.007 494(77)

molar mass: 239.074 790 8(91) $g \cdot mol^{-1}$

4. Date of sample receipt : n.a.
   Date of completion of measurement : 7 November 2006

5. All uncertainties indicated are expanded uncertainties $U = k \cdot u_c$ where u_c is the combined standard uncertainty estimated following the ISO/BIPM guide[1]. They are given in parentheses and include a coverage factor k=2. They apply to the last two digits of the value. The values certified are traceable to the SI. The primary certified values are the isotope amount ratio ; other values are derived from them. Reproducing the derived values may result in difference due to rounding errors.

[1] International Organisation for Standardisation, Guide to the expression of Uncertainty in Measurement, ©ISO, ISBN 92-67-10188-9, Geneva, Switserland, 1993

Uncertainty budget :

Quantity	Value	Standard Uncertainty	Index
Atomic mass ^{239}Pu	239.05215760 g/mol	$5.1 \cdot 10^{-6}$ g/mol	59.6 %
Measurement ratio 240/239	0.02243535 mol/mol	$3.81 \cdot 10^{-6}$ mol/mol	14.9 %
Measurement ratio 241/239	$240 \cdot 10^{-6}$ mol/mol	$450 \cdot 10^{-9}$ mol/mol	0.9 %
Measurement ratio 242/239	$75 \cdot 10^{-6}$ mol/mol	$175 \cdot 10^{-9}$ mol/mol	0.4 %
$variability_{241/239}$	0.0 mol/mol	$2.65 \cdot 10^{-6}$ mol/mol	21.0 %
$variability_{242/239}$	0.0 mol/mol	$650 \cdot 10^{-9}$ mol/mol	3.0 %
M_{Pu}	239.07478500 g/mol	$6.46 \cdot 10^{-6}$ g/mol	

6. The traceability to SI is established through standards from IRMM-290.

7. Analytical measurement procedure
   - Mass spectrometric measurments were performed by H Kühn an F Kehoe for the $[n(^{238}Pu)/n(^{239}Pu)]$, $[n(^{240}Pu)/n(^{239}Pu)]$, $[n(^{241}Pu)/n(^{239}Pu)]$ and $[n(^{242}Pu)/n(^{239}Pu)]$ using the MAT262 TIMS, sample solutions were prepared for TIMS analysis by F Kehoe. A. Verbruggen was responsible for preparation and issuance of the certificate.
   - The atomic masses, used in the calculation are from G. Audi and A.H. Wapstra.[2]
   - Reference numbers of the measurement data: measurements number T26629, T26A03, T26B07, logged in S:\D04-IM\Secure Data\Project Data\MP2 (based on 081a and LSD1027i)\MP2 IA Summary MAT262 measurements.
   - Full details of the preparation and the certification procedure can be found in certification report EUR*****.

8. These samples will be stored for a minimum period of six months from the date of this certificate

André Verbruggen
Group leader Nuclear Chemistry

Stephan Richter
Group leader Nuclear Mass Spectrometry

Copies
P Taylor, IM unit head
Y Aregbe, Action leader Nuclear Safeguards
F Kehoe
H Kühn

[2] G. Audi and A.H. Wapstra, The 2003 atomic mass evaluation, Nucl Phys A729 (2003) 337-676

Annex 6: The certificate of isotopic composition of EC NRM 101 by IRMM

European Commission
JOINT
RESEARCH
CENTRE

Institute for Reference Materials and Measurements
Steenweg op Retie,2440 Geel,Belgium
Tel.(014)571.211-Telex 33589 EURAT B
Telefax 014/58.42.73

CERTIFICATE OF ISOTOPIC COMPOSITION
****

1. Applicant : Dr.K.Mayer
Stable Isotope Measurements
IRMM

2. Sample identification : EC 101

3. Results :

	Amount Ratio(s)	Mass Ratio(s)	Uncertainty (computed on a 2s basis for each element)
n(234U)/n(238U)	0.00005548		+/- 0.00000022
n(235U)/n(238U)	0.007293		+/- 0.0000036
n(236U)/n(238U)	0.000000151		+/- 0.000000040

4. Reference number : SMS 7315

5. Remarks : This sample will be stored for a minimum period of six months from the date of this certificate.

Request received at laboratory : 1995.06.23
Sample received at laboratory : 1995.06.23
Measurement achieved : 1995.06.23
Telephone or telex communication :

Mass spectrometric measurements were performed by W.De Bolle (n(235U)/n(238U) ratio by UF6) and A.Alonso (THMS) on samples chemically prepared by A.Alonso.

The values certified are traceable to the SI system and its unit for amount of substance: the mole.

c. P.De Bievre / A.Alonso

W.DE BOLLE
Stable Isotope Measurements

Annex 7: Report of analysis for NBL CRM-116

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

Institute for Reference Materials and Measurements (Geel)

INTERNAL TEST REPORT # 2731 - NBL CRM-116

Requested by: R. Jakopic, SN3S Unit

Samples

Sample ID	Applicant sample identification
19732	NBL CRM-116

Date of receipt of samples: 15/04/2013.....

Condition of the samples: U nitrate solution.....
.....

Sample ID	Analyte	Result (± expanded uncertainty[1])	Unit	Method[2]
19732 / CRM116	$n(^{238}U)/n(^{235}U)$	0.057975(17)	mol / mol	RM WI/0348
19732 / CRM116	$n(^{234}U)/n(^{235}U)$	0.0106853(11)	mol / mol	RM WI/0348
19732 / CRM116	$n(^{236}U)/n(^{235}U)$	0.00448811(46)	mol / mol	RM WI/0348

Notes:

Notes *(to be deleted if not applicable, also the logo!)*		
	1	Uncertainties are given as *(e.g. expanded (k=2) uncertainties according to the ISO Guide to the Expression of Uncertainty (GUM), corresponding to an approximate 95% confidence interval)*

Files name(s) of raw data:

Data are stored in:
"S:\D02-RM\Nuclear Safeguards\Nuclear\TRITON DATA - SHARED\MTE for EC101 CRM116 SLD 1027o", MTE measurement file: "T130418 EC101 CRM116.xls".....

30/4/2013
Date

Signature
Analyst

Signature
Laboratory Responsible

Annex 8: The certificate of IRMM-046b

CERTIFICATE
SPIKE ISOTOPIC REFERENCE MATERIAL IRMM-046b

$4.650\ 4(18) \cdot 10^{-7}$ mol (^{242}Pu) · g^{-1} (solution)
$4.115\ 38(85) \cdot 10^{-6}$ mol (^{233}U) · g^{-1} (solution)

The Spike Isotopic Reference Material is supplied with an isotope amount content of ^{233}U and ^{242}Pu as certified above.

The amount of other uranium and plutonium isotopes present are related to the ^{233}U and ^{242}Pu content through the following certified amount ratios:

$n(^{238}Pu)/n(^{242}Pu)$	:	0.005 332(20)
$n(^{239}Pu)/n(^{242}Pu)$	:	0.002 212(16)
$n(^{240}Pu)/n(^{242}Pu)$	:	0.046 066(63)
$n(^{241}Pu)/n(^{242}Pu)$	:	0.002 9998(86)
$n(^{244}Pu)/n(^{242}Pu)$	:	0.000 237(31)

$n(^{234}U)/n(^{233}U)$	:	0.009 396(12)
$n(^{235}U)/n(^{233}U)$	:	0.002 252 0(60)
$n(^{236}U)/n(^{233}U)$	:	0.000 280 0(40)
$n(^{238}U)/n(^{233}U)$	:	0.008 186(11)

This corresponds to an isotopic composition with the following abundances:

amount fraction (·100)		mass fraction (·100)	
$n(^{238}Pu)/n(Pu)$	0.504 5(18)	$m(^{238}Pu)/m(Pu)$	0.496 4(18)
$n(^{239}Pu)/n(Pu)$	0.209 3(15)	$m(^{239}Pu)/m(Pu)$	0.206 8(15)
$n(^{240}Pu)/n(Pu)$	4.358 9(57)	$m(^{240}Pu)/m(Pu)$	4.324 8(57)
$n(^{241}Pu)/n(Pu)$	0.283 85(81)	$m(^{241}Pu)/m(Pu)$	0.282 81(81)
$n(^{242}Pu)/n(Pu)$	94.621 0(67)	$m(^{242}Pu)/m(Pu)$	94.666 5(67)
$n(^{244}Pu)/n(Pu)$	0.022 4(29)	$m(^{244}Pu)/m(Pu)$	0.022 6(30)

The molar mass of the plutonium in this sample is 241.942 44(15) g·mol^{-1}

06/2010

	amount fraction (·100)		mass fraction (·100)
$n(^{233}U)/n(U)$	98.028 3(17)	$m(^{233}U)/m(U)$	98.005 3(17)
$n(^{234}U)/n(U)$	0.921 1(12)	$m(^{234}U)/m(U)$	0.924 8(12)
$n(^{235}U)/n(U)$	0.220 76(59)	$m(^{235}U)/m(U)$	0.222 61(59)
$n(^{236}U)/n(U)$	0.027 45(39)	$m(^{236}U)/m(U)$	0.027 80(40)
$n(^{238}U)/n(U)$	0.802 5(11)	$m(^{238}U)/m(U)$	0.819 5(11)

The molar mass of the uranium in this sample is 233.094 320(57) $g \cdot mol^{-1}$

From the certified values, the following amount and mass contents are derived:

$4.914\ 7(19) \cdot 10^{-7}$	mol (Pu) · g^{-1} (solution)
$1.125\ 67(43) \cdot 10^{-4}$	g (^{242}Pu) · g^{-1} (solution)
$1.189\ 09(46) \cdot 10^{-4}$	g (Pu) · g^{-1} (solution)

and

$4.198\ 16(87) \cdot 10^{-6}$	mol (U) · g^{-1} (solution)
$0.959\ 05(20) \cdot 10^{-3}$	g (^{233}U) · g^{-1} (solution)
$0.978\ 57(20) \cdot 10^{-3}$	g (U) · g^{-1} (solution)

NOTES

1. All uncertainties indicated are expanded uncertainties $U = k \cdot u_c$ where u_c is the combined standard uncertainty estimated according to the ISO/BIPM Guide to the Expression of Uncertainty in Measurement. They are given in parentheses and include a coverage factor $k = 2$. They apply to the last two digits of the value.
2. Values for isotope ratios, isotopic compositions and for concentrations are valid for 1 June 2010. This certificate is valid until June 2013; the validity may be extended after further tests on the stability of the spike material are carried out.
3. Due to radioactive decay, the Pu element concentration decreases by 0.035 % · a^{-1}.
4. The half lives used in the calculations are

^{238}Pu: 8.77 (03) · 10^1 a[(1)]

^{239}Pu: 2.411 (03) · 10^4 a[(1)]

^{240}Pu: 6.563 (07) · 10^3 a[(1)]

^{241}Pu: 1.432 5(24) · 10^1 a[(2)]

^{242}Pu: 3.735 (11) · 10^5 a[(1)]

^{244}Pu: 8.00 (09) · 10^7 a[(1]

(1) IAEA, Decay data of the Transactinium Nuclides, Technical Reports Series No. 261, 1986
(2) R. Wellum, A. Verbruggen, R. Kessel, J. Anal. At. Spectrom., 2009, 24, 801 - 807

5. The atomic masses, used in the calculations, are[3]

^{233}U : 233.039 635 2 (58) g·mol^{-1}
^{234}U : 234.040 952 1 (40) g·mol^{-1}
^{235}U : 235.043 929 9 (40) g·mol^{-1}
^{236}U : 236.045 568 0 (40) g·mol^{-1}
^{238}U : 238.050 788 2 (40) g·mol^{-1}

^{238}Pu : 238.049 559 9 (40) g·mol^{-1}
^{239}Pu : 239.052 163 4 (40) g·mol^{-1}
^{240}Pu : 240.053 813 5 (40) g·mol^{-1}
^{241}Pu : 241.056 851 5 (40) g·mol^{-1}
^{242}Pu : 242.058 742 6 (40) g·mol^{-1}
^{244}Pu : 244.064 204 (10) g·mol^{-1}

6. A unit of IRMM-046b consists of a flame-sealed glass ampoule containing a chemically stable solution of uranium and plutonium in nitric acid. The solution volume is about 10 mL; the molarity is about 5 M.

7. The ampoule should be handled with great care and by experienced personnel in a laboratory environment suitably equipped for the safe handling of radioactive materials.

8. Using this Spike Isotopic Reference Material, ^{239}Pu concentrations in unknown samples can be determined by Isotope Dilution Mass Spectrometry, through a measurement of the isotope dilution ratio R_B = $n(^{239}\text{Pu})/n(^{242}\text{Pu})$ in the blend. They should be computed with the aid of the following formula which allows an easy identification and quantification of the sources of the uncertainties in the procedure :

$$c\left(^{239}Pu\right)_X = \frac{R_Y - R_B}{R_B - R_X} \cdot R_X \cdot \frac{m_Y}{m_X} \cdot c\left(^{242}Pu\right)_Y$$

$$c(Pu)_X = \frac{R_Y - R_B}{R_B - R_X} \cdot \frac{\sum R_{Xi}}{\sum R_{Yi}} \cdot \frac{m_Y}{m_X} \cdot c(Pu)_Y$$

where

R_X	=	amount ratio $n(^{239}\text{Pu})/n(^{242}\text{Pu})$ in the unknown sample material
R_Y	=	amount ratio $n(^{239}\text{Pu})/n(^{242}\text{Pu})$ in the spike material
m_X	=	mass of the unknown sample
m_Y	=	mass of the sample of spike solution used
$c\left(^{239}Pu\right)_X$	=	number of moles ^{239}Pu · kg^{-1} sample material
$c\left(^{242}Pu\right)_Y$	=	number of moles ^{242}Pu · kg^{-1} spike solution
$c(Pu)_X$	=	number of moles Pu · kg^{-1} sample material
$c(Pu)_Y$	=	number of moles Pu · kg^{-1} spike solution.

[3] G. Audi and A.H. Wapstra, The 2003 atomic mass evaluation, Nucl Phys A729 (2003) 337-676.

9. Using this Spike Isotopic Reference Material, ^{235}U concentrations in unknown samples can be determined by Isotope Dilution Mass Spectrometry, through a measurement of the isotope dilution ratio $R_B = n(^{233}U)/n(^{235}U)$ in the blend. They should be computed with the aid of the following formula which allows an easy identification and quantification of the sources of the uncertainties in the procedure :

$$c\left(^{235}U\right)_X = \frac{R_Y - R_B}{R_B - R_X} \cdot \frac{1}{R_Y} \cdot \frac{m_Y}{m_X} \cdot c\left(^{233}U\right)_Y$$

$$c(U)_X = \frac{R_Y - R_B}{R_B - R_X} \cdot \frac{\sum R_{Xi}}{\sum R_{Yi}} \cdot \frac{m_Y}{m_X} \cdot c(U)_Y$$

where

R_X	=	amount ratio $n(^{233}U)/n(^{235}U)$ in the unknown sample material
R_Y	=	amount ratio $n(^{233}U)/n(^{235}U)$ in the spike material
m_X	=	mass of the unknown sample
m_Y	=	mass of the sample of spike solution used
$c\left(^{235}U\right)_X$	=	number of moles $^{235}U \cdot kg^{-1}$ sample material
$c\left(^{233}U\right)_Y$	=	number of moles $^{233}U \cdot kg^{-1}$ spike solution
$c(U)_X$	=	number of moles $U \cdot kg^{-1}$ sample material
$c(U)_Y$	=	number of moles $U \cdot kg^{-1}$ spike solution.

10. The certified values of this Spike Isotopic Reference Material are metrologically traceable to the SI. Measurements calibrated with this Isotopic Reference Materials can therefore provide SI-traceable results.

11. The isotopic measurements by Thermal Ionisation Mass Spectrometry were performed by H. Kühn, F. Kehoe and S. Richter for uranium and for plutonium. Isotopic measurements were calibrated against synthetic plutonium isotope mixtures prepared by J. Broothaerts. Chemical preparation of the samples for isotope measurements was performed by F. Kehoe and R. Jakopič.

Metrological weighings for the preparation and certification were performed by U. Jacobsson and R. Eykens. The ampoulation of this Spike Isotopic Reference Material was accomplished by G. Van Baelen and A. Verbruggen.

The overall co-ordination leading to the establishment, certification and issuance of this Spike Isotopic Reference Material was performed by A. Verbruggen.

Geel, June 2010

H. Emons
Head
Reference Materials Unit

06/2010

Annex 9: Results of the IDMS confirmation measurements for ^{235}U and ^{239}Pu amount contents in the solution of IRMM-1027o.

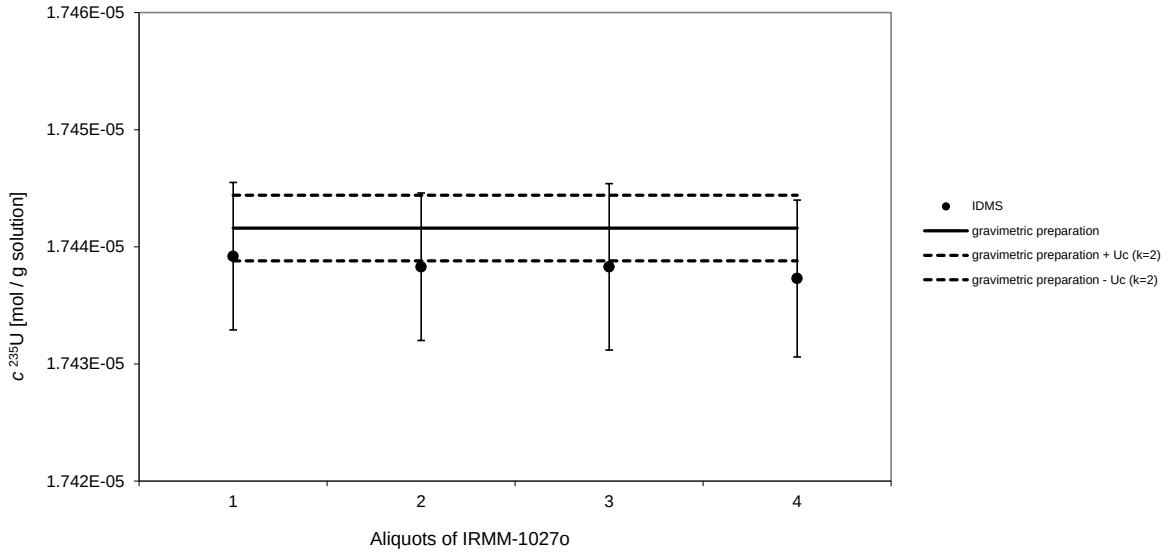


Fig 3. The amount content of ^{235}U in the solution of IRMM-1027o prepared by gravimetric mixing compared with the measured values by IDMS (with expanded uncertainties, coverage factor *k*=2).

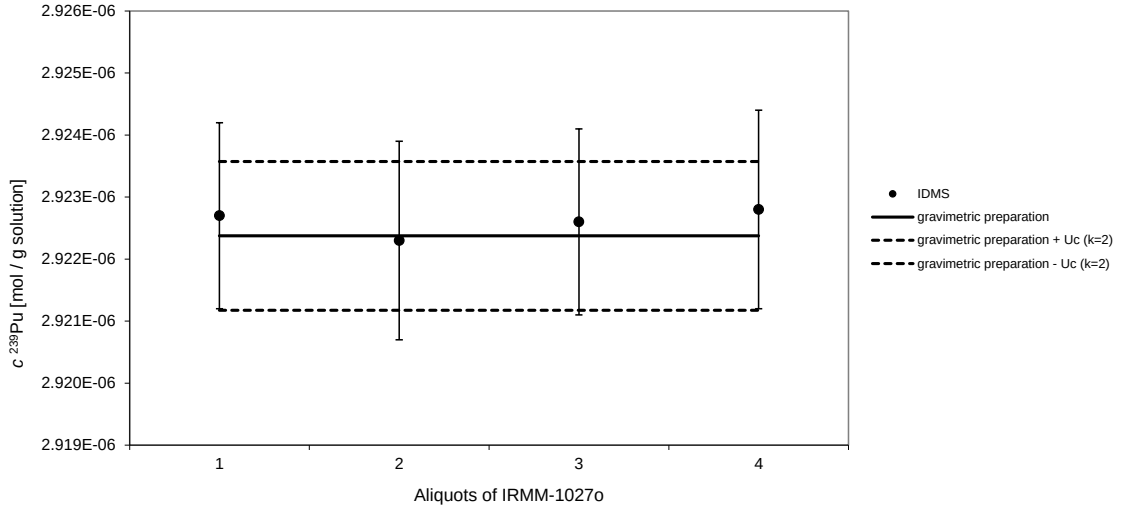


Fig 4. The amount content of ^{239}Pu in the solution of IRMM-1027o prepared by gravimetric mixing compared with the measured values by IDMS (with expanded uncertainties, coverage factor *k*=2).

Annex 10: Results of the confirmation measurements of the plutonium and uranium isotope amount ratios in an aliquot of IRMM-1027o solution by TIMS.

	Gravimetric preparation		Confirmation by TIMS	
Isotope amount ratios	Value [1)] [mol/mol]	U (k=2) [mol/mol]	Value [1)] [mol/mol]	U (k=2) [mol/mol]
$n(^{238}Pu)/n(^{239}Pu)$	0.00002945	0.00000028	0.0000404	0.0000013
$n(^{240}Pu)/n(^{239}Pu)$	0.0224223	0.0000051	0.0224256	0.0000029
$n(^{241}Pu)/n(^{239}Pu)$	0.0001793	0.0000024	0.0001825	0.0000021
$n(^{242}Pu)/n(^{239}Pu)$	0.00007571	0.00000078	0.0000765	0.0000011
$n(^{234}U)/n(^{238}U)$	0.00256817	0.00000061	0.0025708	0.0000023
$n(^{235}U)/n(^{238}U)$	0.242385	0.000048	0.242537	0.000090
$n(^{236}U)/n(^{238}U)$	0.00105586	0.00000024	0.0010616	0.0000034

[1)] The reference date for the plutonium and uranium isotope amount ratios is November 1, 2012.

Annex 11: Results of the homogeneity assessment of the selected vials of IRMM-1027o for the ^{239}Pu, ^{238}U and ^{235}U amount contents.

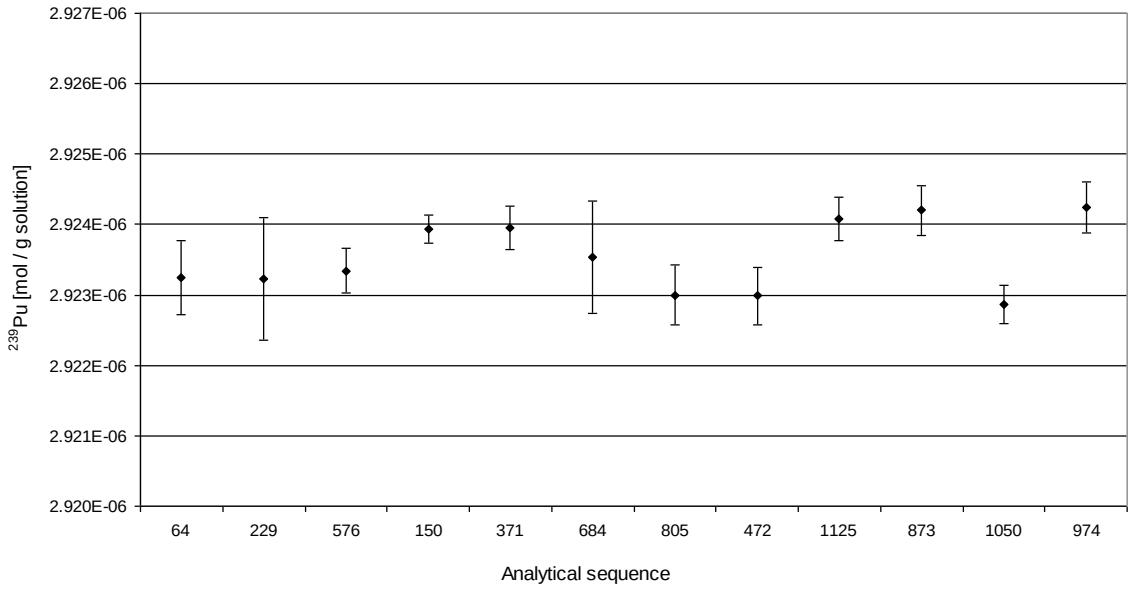


Fig 5. The results (average ± standard deviation) of the homogeneity assessment of the ^{239}Pu amount content in the selected vials of IRMM-1027o.

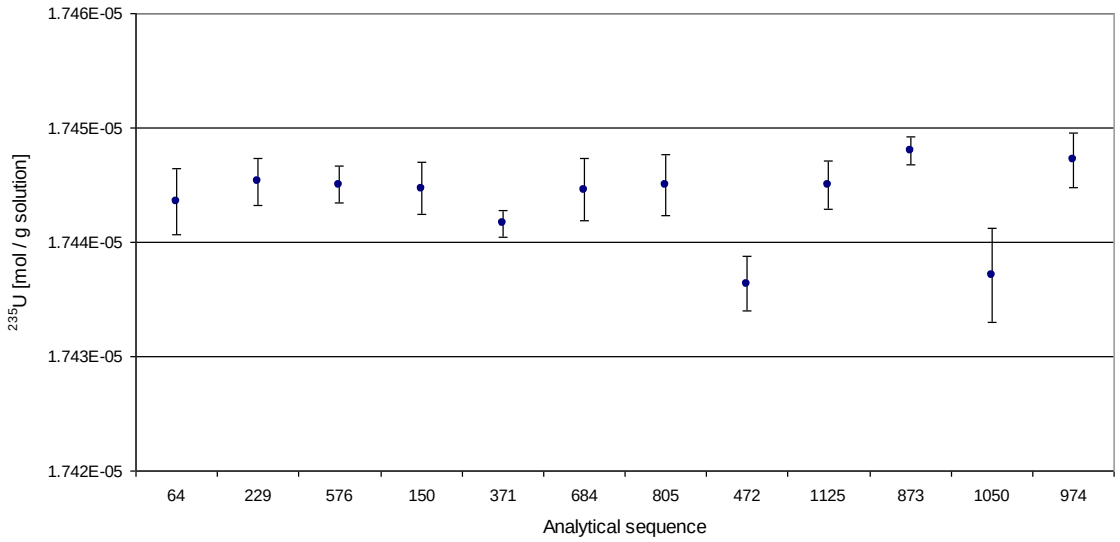


Fig 6. The results (average ± standard deviation) of the homogeneity assessment of the ^{235}U amount content in the selected vials of IRMM-1027o.

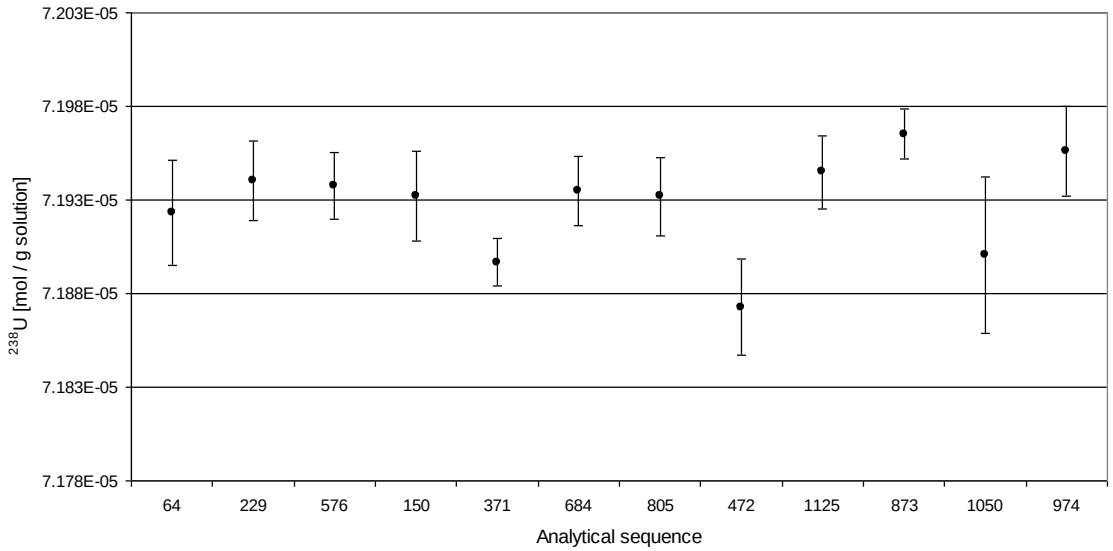


Fig 7. The results (average + standard deviation) of the homogeneity assessment of the ^{238}U amount content in the selected vials of IRMM-1027o.

Annex 12: Results of the confirmation measurements of ^{235}U, ^{238}U and ^{239}Pu amount contents in the selected vials of IRMM-1027o.

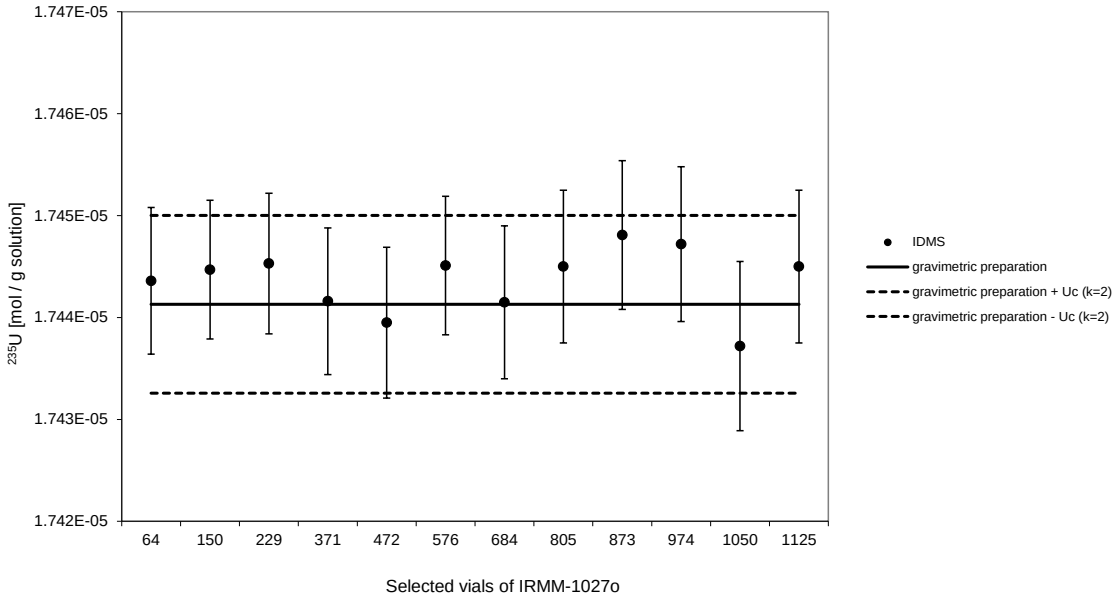


Fig 8. The certified amount content of ^{235}U in the selected vials of IRMM-1027o prepared by gravimetric mixing compared with the measured values by IDMS (with expanded uncertainties, coverage factor *k*=2).

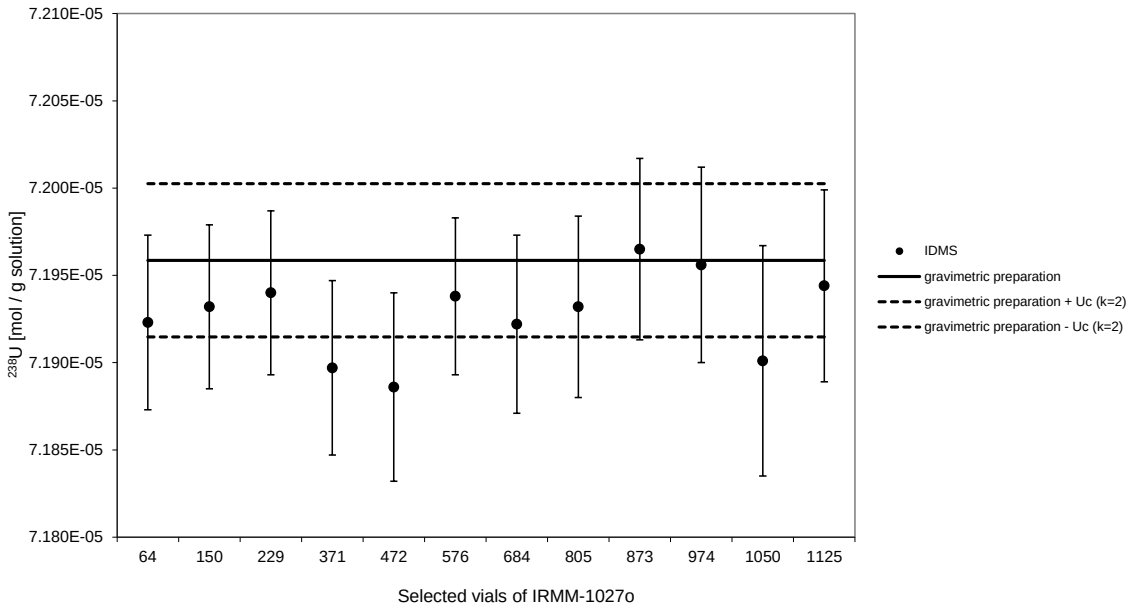


Fig 9. The certified amount content of ^{238}U in the selected vials of IRMM-1027o prepared by gravimetric mixing compared with the measured values by IDMS (with expanded uncertainties, coverage factor *k*=2).

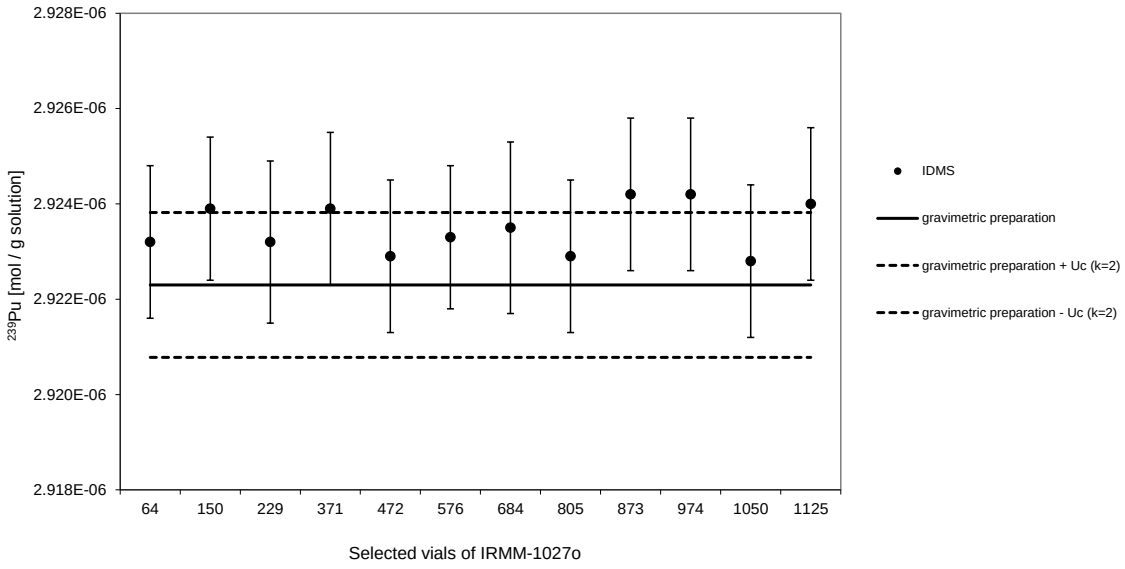


Fig 10. The certified amount content of ^{239}Pu in the selected vials of IRMM-1027o prepared by gravimetric mixing compared with the measured values by IDMS (with expanded uncertainties, coverage factor *k*=2)

Annex 13: The weighing certificate of the aliquots of dispensed solution per unit before drying.

European Commission	**Certificate of weighing**	Institute for Reference Materials and Measurements

E. 3832 **Issue date**: 2012-07-27

Applicant: Rožle Jakopič **Group:** Nuclear SG

Project: LN project: RM PP-0222, IRMM-1027O Preparation and Certification of Large-sized dried (LSD) spikes

Description: 1027O individual vials Nr 1027O-0001 to 1027O-1215.

Date of receipt of request: N/A **Weighing date:** 2012-04-23 – 04-27

Results:

The reported results apply only to the objects / samples described in this certificate, and are shown in the annex.

Observations:

The measurements and uncertainty estimates, were performed according to working instruction RM-WI-0368, "LSD automated system equipment manual" on balance Sartorius TE124 installed in a dispensing robot, Nucomat with IRMM inventory no 2006 00290 17.

Traceability:

The certified mass values are traceable to the International Kilogram Prototype via regular calibrations of the IRMM principal mass standards. The mass standard identified as H208 (cylinder + vial certificate IRMM E3612) was used as verification of balance performance in the mass determination.

Uncertainty:

All reported uncertainties are expanded uncertainties $U = k \cdot u_c$ where u_c is the combined standard uncertainty calculated according to the ISO/BIPM Guide to the expression of Uncertainty in Measurement. The coverage factor $k = 2$ corresponds to a coverage probability of about 95%
U has a value of 0.0006 g for the annexed results.

Annex : Weighing results

.....
Signature
Nuclear SG analyst

.....
Signature
Mass Metrology

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The mission of IRMM is to promote a common and reliable European measurement system in support of EU policies.

European Commission	Certificate of weighing Annex	Institute for Reference Materials and Measurements

E. 3832 **Issue date**: 2012-07-27

Annex 1: List of vial numbers IRMM1027O, mass of solution before drying. Page 1 of 7

Vial nr	Mass (g)	Vial nr	Mass (g)	Vial nr	Mass (g)	Vial nr	Mass (g)
0001	2.5150	0051	2.5135	0101	2.5346	0151	2.5320
0002	2.5153	0052	2.5157	0102	2.5357	0152	2.5384
0003	2.5151	0053	2.5145	0103	2.5352	0153	2.5340
0004	2.5157	0054	2.5148	0104	2.5358	0154	2.4870
0005	2.5151	0055	2.5139	0105	2.5344	0155	2.5371
0006	2.5140	0056	2.5155	0106	2.5331	0156	2.5369
0007	2.5160	0057	2.5135	0107	2.5348	0157	2.5361
0008	2.5153	0058	2.5146	0108	2.5380	0158	2.5340
0009	2.5148	0059	2.5143	0109	2.5346	0159	2.5371
0010	2.5148	0060	2.5148	0110	2.5357	0160	2.5361
0011	2.5139	0061	2.5144	0111	2.5362	0161	2.5356
0012	2.5157	0062	2.5152	0112	2.5342	0162	2.5367
0013	2.5125	0063	2.5131	0113	2.5359	0163	2.5367
0014	2.5129	0064	2.5151	0114	2.5357	0164	2.5345
0015	2.5140	0065	2.5136	0115	2.5349	0165	2.5358
0016	2.5143	0066	2.5139	0116	2.5368	0166	2.5371
0017	2.5150	0067	2.5144	0117	2.5344	0167	2.5365
0018	2.5141	0068	2.5147	0118	2.5349	0168	2.5349
0019	2.5140	0069	2.5155	0119	2.5363	0169	2.5344
0020	2.5134	0070	2.5131	0120	2.5344	0170	2.5367
0021	2.5178	0071	2.5134	0121	2.5361	0171	2.5359
0022	2.5150	0072	2.5145	0122	2.5355	0172	2.5358
0023	2.5133	0073	2.5140	0123	2.5339	0173	2.5360
0024	2.5146	0074	2.5148	0124	2.5359	0174	2.5369
0025	2.5146	0075	2.5136	0125	2.5354	0175	2.5350
0026	2.5150	0076	2.5163	0126	2.5352	0176	2.5367
0027	2.5136	0077	2.5129	0127	2.5356	0177	2.5358
0028	2.5126	0078	2.5138	0128	2.5354	0178	2.5349
0029	2.5158	0079	2.5151	0129	2.5359	0179	2.5353
0030	2.5137	0080	2.5139	0130	2.5338	0180	2.5371
0031	2.5139	0081	2.5143	0131	2.5358	0181	2.5354
0032	2.5142	0082	2.5142	0132	2.5349	0182	2.5349
0033	2.5140	0083	2.5149	0133	2.5357	0183	2.5366
0034	2.5150	0084	2.5140	0134	2.5346	0184	2.5356
0035	2.5134	0085	2.5148	0135	2.5365	0185	2.5351
0036	2.5146	0086	2.5142	0136	2.5364	0186	2.5376
0037	2.5140	0087	2.5146	0137	2.5352	0187	2.5344
0038	2.5158	0088	2.5147	0138	2.5360	0188	2.5350
0039	2.5115	0089	2.5141	0139	2.5366	0189	2.5353
0040	2.5156	0090	2.5147	0140	2.5349	0190	2.5344
0041	2.5128	0091	2.5147	0141	2.5354	0191	2.5350
0042	2.5155	0092	2.5129	0142	2.5362	0192	2.5359
0043	2.5145	0093	2.5161	0143	2.5374	0193	2.5362
0044	2.5118	0094	2.5142	0144	2.5354	0194	2.5342
0045	2.5138	0095	2.5153	0145	2.5365	0195	2.5348
0046	2.5141	0096	2.5143	0146	2.5341	0196	2.5355
0047	2.5152	0097	2.5344	0147	2.5328	0197	2.5345
0048	2.5135	0098	2.5362	0148	2.4880	0198	2.5369
0049	2.5138	0099	2.5345	0149	2.5351	0199	2.5368
0050	2.5138	0100	2.5355	0150	2.5365	0200	2.5335

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E.3832 . **Issue date:** 2012-07-257

Annex 1: List of vial numbers IRMM1027O, mass of solution before drying. Page 2 of 7

Vial nr	Mass (g)	Vial nr	Mass (g)	Vial nr	Mass (g)	Vial nr	Mass (g)
0201	2.5356	0251	2.5330	0301	2.5330	0351	2.5367
0202	2.5349	0252	2.4869	0302	2.5337	0352	2.5305
0203	2.4876	0253	2.5319	0303	2.5336	0353	2.5367
0204	2.5338	0254	2.5353	0304	2.5353	0354	2.5306
0205	2.5363	0255	2.4868	0305	2.5324	0355	2.5369
0206	2.5362	0256	2.5334	0306	2.5313	0356	2.5315
0207	2.5353	0257	2.5346	0307	2.5354	0357	2.4869
0208	2.5337	0258	2.5370	0308	2.5336	0358	2.5303
0209	2.5356	0259	2.5320	0309	2.5351	0359	2.5332
0210	2.5379	0260	2.5376	0310	2.5310	0360	2.5336
0211	2.5342	0261	2.5361	0311	2.5335	0361	2.5345
0212	2.5331	0262	2.5354	0312	2.5334	0362	2.5354
0213	2.5356	0263	2.5345	0313	2.5337	0363	2.5314
0214	2.5355	0264	2.5355	0314	2.5330	0364	2.5343
0215	2.5354	0265	2.5355	0315	2.5348	0365	2.5346
0216	2.5355	0266	2.5354	0316	2.5355	0366	2.4876
0217	2.5374	0267	2.5329	0317	2.5315	0367	2.5294
0218	2.5338	0268	2.5341	0318	2.5331	0368	2.4871
0219	2.5376	0269	2.5356	0319	2.5339	0369	2.5287
0220	2.5330	0270	2.5345	0320	2.5353	0370	2.5364
0221	2.5352	0271	2.5332	0321	2.5346	0371	2.5313
0222	2.5377	0272	2.5340	0322	2.5310	0372	2.5306
0223	2.5331	0273	2.5356	0323	2.5343	0373	2.5371
0224	2.5339	0274	2.5355	0324	2.5370	0374	2.5350
0225	2.5337	0275	2.5358	0325	2.5314	0375	2.4874
0226	2.5377	0276	2.5336	0326	2.5322	0376	2.5311
0227	2.5354	0277	2.5359	0327	2.5360	0377	2.5316
0228	2.5344	0278	2.5320	0328	2.5322	0378	2.5390
0229	2.5368	0279	2.5358	0329	2.5327	0379	2.5348
0230	2.5342	0280	2.4870	0330	2.4888	0380	2.5297
0231	2.5353	0281	2.5335	0331	2.5316	0381	2.5360
0232	2.5366	0282	2.5334	0332	2.5316	0382	2.5338
0233	2.5354	0283	2.5349	0333	2.5353	0383	2.5319
0234	2.5332	0284	2.5342	0334	2.5307	0384	2.5328
0235	2.5344	0285	2.5352	0335	2.4903	0385	2.5335
0236	2.5375	0286	2.5349	0336	2.5283	0386	2.4876
0237	2.5329	0287	2.5355	0337	2.5387	0387	2.5323
0238	2.5352	0288	2.5324	0338	2.5329	0388	2.4872
0239	2.5331	0289	2.4889	0339	2.5316	0389	2.5335
0240	2.5355	0290	2.5320	0340	2.5341	0390	2.5303
0241	2.5363	0291	2.5325	0341	2.5348	0391	2.5379
0242	2.5356	0292	2.5339	0342	2.4873	0392	2.5330
0243	2.5341	0293	2.5290	0343	2.5335	0393	2.5307
0244	2.5349	0294	2.4875	0344	2.5339	0394	2.5337
0245	2.5328	0295	2.5293	0345	2.5352	0395	2.5399
0246	2.4870	0296	2.5330	0346	2.5325	0396	2.5330
0247	2.5345	0297	2.5363	0347	2.5341	0397	2.5298
0248	2.5371	0298	2.5323	0348	2.5348	0398	2.5350
0249	2.5329	0299	2.5336	0349	2.5358	0399	2.5334
0250	2.5364	0300	2.5357	0350	2.5330	0400	2.4875

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Annex 1: List of vial numbers IRMM1027O, mass of solution before drying. Page 3 of 7

Vial nr	Mass (g)	Vial nr	Mass (g)	Vial nr	Mass (g)	Vial nr	Mass (g)
0401	2.5301	0451	2.5314	0501	2.5400	0551	2.4872
0402	2.5329	0452	2.5360	0502	2.5279	0552	2.5284
0403	2.5322	0453	2.5323	0503	2.5313	0553	2.5294
0404	2.5372	0454	2.5318	0504	2.5287	0554	2.5301
0405	2.5310	0455	2.5334	0505	2.5402	0555	2.5331
0406	2.5345	0456	2.5340	0506	2.5256	0556	2.5329
0407	2.5382	0457	2.5312	0507	2.5313	0557	2.5302
0408	2.5298	0458	2.5330	0508	2.5366	0558	2.5334
0409	2.5326	0459	2.5304	0509	2.5289	0559	2.5345
0410	2.5411	0460	2.4885	0510	2.4864	0560	2.5291
0411	2.5277	0461	2.5312	0511	2.5301	0561	2.5338
0412	2.5328	0462	2.5305	0512	2.5322	0562	2.5314
0413	2.5351	0463	2.5361	0513	2.5308	0563	2.5373
0414	2.5310	0464	2.5303	0514	2.5335	0564	2.5251
0415	2.5352	0465	2.5399	0515	2.5312	0565	2.5345
0416	2.5294	0466	2.5252	0516	2.5321	0566	2.5303
0417	2.4891	0467	2.4867	0517	2.5324	0567	2.5353
0418	2.5325	0468	2.5300	0518	2.5348	0568	2.5328
0419	2.5348	0469	2.5326	0519	2.5311	0569	2.5313
0420	2.5277	0470	2.5323	0520	2.5338	0570	2.5305
0421	2.5365	0471	2.5348	0521	2.5314	0571	2.5317
0422	2.5299	0472	2.5355	0522	2.5392	0572	2.5367
0423	2.5370	0473	2.5326	0523	2.5291	0573	2.5289
0424	2.5286	0474	2.5314	0524	2.5278	0574	2.5336
0425	2.5315	0475	2.4878	0525	2.5317	0575	2.5330
0426	2.5325	0476	2.5288	0526	2.5327	0576	2.5304
0427	2.4886	0477	2.5308	0527	2.5346	0577	2.4899
0428	2.5299	0478	2.4886	0528	2.5321	0578	2.5251
0429	2.5360	0479	2.5335	0529	2.5296	0579	2.5325
0430	2.5310	0480	2.5251	0530	2.5408	0580	2.5319
0431	2.5332	0481	2.4869	0531	2.5221	0581	2.5307
0432	2.5339	0482	2.5291	0532	2.5362	0582	2.5328
0433	2.5324	0483	2.5339	0533	2.5299	0583	2.5272
0434	2.5339	0484	2.5328	0534	2.5347	0584	2.5289
0435	2.5369	0485	2.5382	0535	2.5305	0585	2.5339
0436	2.5272	0486	2.5279	0536	2.5306	0586	2.5308
0437	2.5385	0487	2.5324	0537	2.4864	0587	2.5265
0438	2.5274	0488	2.5339	0538	2.5256	0588	2.4869
0439	2.5380	0489	2.5300	0539	2.5333	0589	2.5280
0440	2.5278	0490	2.5311	0540	2.5334	0590	2.5259
0441	2.5315	0491	2.4915	0541	2.5327	0591	2.5339
0442	2.5343	0492	2.5293	0542	2.5296	0592	2.5367
0443	2.5352	0493	2.5331	0543	2.5341	0593	2.5247
0444	2.5389	0494	2.5349	0544	2.5320	0594	2.5350
0445	2.5264	0495	2.5370	0545	2.5296	0595	2.5265
0446	2.5331	0496	2.5260	0546	2.5422	0596	2.4900
0447	2.5340	0497	2.5314	0547	2.5238	0597	2.5255
0448	2.5354	0498	2.5359	0548	2.5368	0598	2.5292
0449	2.5272	0499	2.5345	0549	2.5326	0599	2.5310
0450	2.5378	0500	2.5292	0550	2.5291	0600	2.4884

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E. 3832 **Issue date:** 2012-07-27

Annex 1: List of vial numbers IRMM1027O, mass of solution before drying. Page 4 of 7

Vial nr	Mass (g)	Vial nr	Mass (g)	Vial nr	Mass (g)	Vial nr	Mass (g)
0601	2.5252	0651	2.5277	0701	2.5345	0751	2.5249
0602	2.5305	0652	2.4874	0702	2.5337	0752	2.5228
0603	2.5343	0653	2.5277	0703	2.5368	0753	2.4890
0604	2.5280	0654	2.5236	0704	2.5308	0754	2.5232
0605	2.5322	0655	2.5339	0705	2.5296	0755	2.4869
0606	2.5320	0656	2.5353	0706	2.5244	0756	2.5198
0607	2.5320	0657	2.5268	0707	2.4868	0757	2.5326
0608	2.5330	0658	2.5341	0708	2.5269	0758	2.5282
0609	2.5296	0659	2.5329	0709	2.5327	0759	2.5238
0610	2.5340	0660	2.5313	0710	2.5361	0760	2.4889
0611	2.5401	0661	2.4870	0711	2.5312	0761	2.5262
0612	2.5285	0662	2.5332	0712	2.5284	0762	2.5336
0613	2.5272	0663	2.5276	0713	2.5338	0763	2.5257
0614	2.5280	0664	2.5345	0714	2.5306	0764	2.5378
0615	2.5316	0665	2.5328	0715	2.5354	0765	2.5174
0616	2.5334	0666	2.5257	0716	2.5266	0766	2.5357
0617	2.5344	0667	2.5324	0717	2.5373	0767	2.5238
0618	2.5241	0668	2.5379	0718	2.5276	0768	2.5349
0619	2.4884	0669	2.5258	0719	2.5324	0769	2.5291
0620	2.5285	0670	2.5309	0720	2.5334	0770	2.5223
0621	2.5332	0671	2.5386	0721	2.5238	0771	2.5259
0622	2.5290	0672	2.5231	0722	2.5351	0772	2.4867
0623	2.5287	0673	2.5299	0723	2.4866	0773	2.5320
0624	2.5358	0674	2.4962	0724	2.5219	0774	2.5309
0625	2.5385	0675	2.5222	0725	2.5328	0775	2.5298
0626	2.5236	0676	2.4867	0726	2.4886	0776	2.5357
0627	2.5369	0677	2.5259	0727	2.5224	0777	2.5181
0628	2.5250	0678	2.5396	0728	2.5366	0778	2.4887
0629	2.5360	0679	2.5310	0729	2.5257	0779	2.5165
0630	2.5294	0680	2.5297	0730	2.5280	0780	2.4904
0631	2.5356	0681	2.5244	0731	2.4866	0781	2.5355
0632	2.5359	0682	2.5345	0732	2.5228	0782	2.5216
0633	2.5268	0683	2.5352	0733	2.4930	0783	2.5368
0634	2.5327	0684	2.5362	0734	2.5214	0784	2.5221
0635	2.5392	0685	2.5270	0735	2.5261	0785	2.5273
0636	2.5331	0686	2.5369	0736	2.5383	0786	2.5329
0637	2.5316	0687	2.5273	0737	2.4879	0787	2.5271
0638	2.5330	0688	2.5294	0738	2.5240	0788	2.5217
0639	2.5286	0689	2.5310	0739	2.5336	0789	2.4886
0640	2.5361	0690	2.4905	0740	2.5252	0790	2.5258
0641	2.5299	0691	2.5274	0741	2.5385	0791	2.5184
0642	2.5344	0692	2.5316	0742	2.5252	0792	2.5303
0643	2.5268	0693	2.5351	0743	2.4872	0793	2.5337
0644	2.5313	0694	2.5257	0744	2.5200	0794	2.5249
0645	2.5351	0695	2.5365	0745	2.4874	0795	2.4879
0646	2.5316	0696	2.5315	0746	2.5258	0796	2.5195
0647	2.5330	0697	2.5303	0747	2.5331	0797	2.5330
0648	2.5263	0698	2.5364	0748	2.5367	0798	2.5264
0649	2.5352	0699	2.5303	0749	2.5281	0799	2.5280
0650	2.5300	0700	2.5299	0750	2.5297	0800	2.5384

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Annex 1: List of vial numbers IRMM1027O, mass of solution before drying. Page 5 of 7

Vial nr	Mass (g)	Vial nr	Mass (g)	Vial nr	Mass (g)	Vial nr	Mass (g)
0801	2.5185	0851	2.5282	0901	2.5245	0951	2.5330
0802	2.5335	0852	2.5207	0902	2.5147	0952	2.5232
0803	2.5212	0853	2.5305	0903	2.5330	0953	2.5192
0804	2.4901	0854	2.5239	0904	2.5295	0954	2.5295
0805	2.5267	0855	2.5295	0905	2.5188	0955	2.5134
0806	2.5156	0856	2.5213	0906	2.5155	0956	2.5240
0807	2.5376	0857	2.5288	0907	2.5275	0957	2.5216
0808	2.5281	0858	2.5329	0908	2.5242	0958	2.5277
0809	2.5297	0859	2.5195	0909	2.5258	0959	2.5266
0810	2.5264	0860	2.5294	0910	2.5356	0960	2.5209
0811	2.5146	0861	2.5335	0911	2.5135	0961	2.5217
0812	2.5365	0862	2.5191	0912	2.5230	0962	2.5341
0813	2.5304	0863	2.5243	0913	2.5280	0963	2.5202
0814	2.5219	0864	2.5238	0914	2.5312	0964	2.5270
0815	2.5325	0865	2.4866	0915	2.5238	0965	2.5248
0816	2.5291	0866	2.5260	0916	2.5315	0966	2.5151
0817	2.4871	0867	2.5217	0917	2.5111	0967	2.5227
0818	2.5182	0868	2.5300	0918	2.5259	0968	2.5355
0819	2.5336	0869	2.5210	0919	2.5251	0969	2.5145
0820	2.5177	0870	2.5314	0920	2.5254	0970	2.5270
0821	2.5267	0871	2.5249	0921	2.5251	0971	2.5302
0822	2.5218	0872	2.5331	0922	2.5280	0972	2.5194
0823	2.5262	0873	2.5342	0923	2.5268	0973	2.5180
0824	2.5361	0874	2.5147	0924	2.5264	0974	2.5267
0825	2.5218	0875	2.5272	0925	2.5257	0975	2.5300
0826	2.5275	0876	2.5224	0926	2.5137	0976	2.5126
0827	2.5288	0877	2.5370	0927	2.5258	0977	2.5280
0828	2.5205	0878	2.5193	0928	2.5252	0978	2.5201
0829	2.5260	0879	2.5297	0929	2.5239	0979	2.5233
0830	2.5261	0880	2.5275	0930	2.5238	0980	2.5264
0831	2.4888	0881	2.5184	0931	2.5238	0981	2.5201
0832	2.5187	0882	2.5215	0932	2.5258	0982	2.5239
0833	2.5380	0883	2.5291	0933	2.5260	0983	2.5237
0834	2.5149	0884	2.5337	0934	2.5302	0984	2.5253
0835	2.5277	0885	2.5230	0935	2.5202	0985	2.5332
0836	2.5350	0886	2.5266	0936	2.5211	0986	2.5217
0837	2.5203	0887	2.5146	0937	2.5307	0987	2.5148
0838	2.5354	0888	2.5323	0938	2.5151	0988	2.5234
0839	2.5277	0889	2.5221	0939	2.5248	0989	2.5258
0840	2.5255	0890	2.5288	0940	2.5371	0990	2.5205
0841	2.5199	0891	2.5219	0941	2.5094	0991	2.5284
0842	2.5232	0892	2.5240	0942	2.5259	0992	2.5261
0843	2.5346	0893	2.5191	0943	2.5253	0993	2.5175
0844	2.5316	0894	2.5322	0944	2.5225	0994	2.5366
0845	2.5183	0895	2.5250	0945	2.5351	0995	2.5139
0846	2.5348	0896	2.5237	0946	2.5119	0996	2.5185
0847	2.5243	0897	2.5302	0947	2.5265	0997	2.5273
0848	2.5216	0898	2.5216	0948	2.5339	0998	2.5267
0849	2.5256	0899	2.5209	0949	2.5125	0999	2.5131
0850	2.5244	0900	2.5306	0950	2.5235	1000	2.5319

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Annex 1: List of vial numbers IRMM1027O, mass of solution before drying. Page 6 of 7

Vial nr	Mass (g)	Vial nr	Mass (g)	Vial nr	Mass (g)	Vial nr	Mass (g)
1001	2.5216	1051	2.5275	1101	2.5200	1151	2.5321
1002	2.5130	1052	2.5147	1102	2.5207	1152	2.5117
1003	2.5326	1053	2.5280	1103	2.5284	1153	2.5257
1004	2.5144	1054	2.5245	1104	2.5122	1154	2.5172
1005	2.5246	1055	2.5168	1105	2.5242	1155	2.5291
1006	2.5201	1056	2.5167	1106	2.5269	1156	2.5195
1007	2.5359	1057	2.5285	1107	2.5138	1157	2.5302
1008	2.5118	1058	2.5164	1108	2.5221	1158	2.5176
1009	2.5332	1059	2.5330	1109	2.5323	1159	2.5267
1010	2.5240	1060	2.5256	1110	2.5197	1160	2.5236
1011	2.5111	1061	2.5122	1111	2.5237	1161	2.5194
1012	2.5242	1062	2.5243	1112	2.5206	1162	2.5224
1013	2.5327	1063	2.5216	1113	2.5194	1163	2.5212
1014	2.5252	1064	2.5245	1114	2.5314	1164	2.5285
1015	2.5197	1065	2.5285	1115	2.5173	1165	2.5180
1016	2.5234	1066	2.5178	1116	2.5260	1166	2.5200
1017	2.5154	1067	2.5247	1117	2.5268	1167	2.5287
1018	2.5216	1068	2.5316	1118	2.5107	1168	2.5209
1019	2.5213	1069	2.5210	1119	2.5356	1169	2.5187
1020	2.5312	1070	2.5214	1120	2.5159	1170	2.5291
1021	2.5178	1071	2.5169	1121	2.5172	1171	2.5301
1022	2.5170	1072	2.5287	1122	2.5329	1172	2.5125
1023	2.5240	1073	2.5204	1123	2.5232	1173	2.5214
1024	2.5306	1074	2.5300	1124	2.5193	1174	2.5238
1025	2.5186	1075	2.5110	1125	2.5123	1175	2.5221
1026	2.5230	1076	2.5350	1126	2.5282	1176	2.5171
1027	2.5286	1077	2.5097	1127	2.5331	1177	2.5277
1028	2.5183	1078	2.5202	1128	2.5122	1178	2.5211
1029	2.5254	1079	2.5212	1129	2.5324	1179	2.5243
1030	2.5183	1080	2.5197	1130	2.5123	1180	2.5231
1031	2.5189	1081	2.5223	1131	2.5222	1181	2.5184
1032	2.5330	1082	2.5376	1132	2.5301	1182	2.5184
1033	2.5199	1083	2.5108	1133	2.5155	1183	2.5251
1034	2.5176	1084	2.5189	1134	2.5214	1184	2.5223
1035	2.5209	1085	2.5320	1135	2.5234	1185	2.5212
1036	2.5237	1086	2.5122	1136	2.5282	1186	2.5136
1037	2.5277	1087	2.5200	1137	2.5220	1187	2.5218
1038	2.5158	1088	2.5318	1138	2.5156	1188	2.5293
1039	2.5224	1089	2.5172	1139	2.5289	1189	2.5174
1040	2.5258	1090	2.5141	1140	2.5227	1190	2.5291
1041	2.5169	1091	2.5229	1141	2.5135	1191	2.5173
1042	2.5277	1092	2.5287	1142	2.5209	1192	2.5205
1043	2.5297	1093	2.5118	1143	2.5260	1193	2.5145
1044	2.5143	1094	2.5237	1144	2.5240	1194	2.5299
1045	2.5285	1095	2.5256	1145	2.5177	1195	2.5113
1046	2.5209	1096	2.5224	1146	2.5323	1196	2.5284
1047	2.5146	1097	2.5158	1147	2.5200	1197	2.5211
1048	2.5249	1098	2.5216	1148	2.5244	1198	2.5163
1049	2.5207	1099	2.5288	1149	2.5145	1199	2.5272
1050	2.5278	1100	2.5245	1150	2.5182	1200	2.5226

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Annex 1:List of vial numbers IRMM1027O, mass of solution before drying. Page 7 of 7

Vial nr	Mass (g)	Vial nr	Mass (g)	Vial nr	Mass (g)	Vial nr	Mass (g)
1200	2.5226						
1201	2.5157						
1202	2.5209						
1203	2.5156						
1204	2.5328						
1205	2.5196						
1208	2.5221						
1207	2.5165						
1206	2.5285						
1209	2.5170						
1210	2.5222						
1211	2.5227						
1212	2.5252						
1213	2.5233						
1214	2.5365						
1215	2.5071						

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Annex 14: The weighing certificate of the metals and the mother solution for the preparation of IRMM-1027o

EUROPEAN COMMISSION DIRECTORATE GENERAL Joint Research Centre	**Certificate of weighing**	Institute for Reference Materials and Measurements

E. 3788 **Issued date**: 05 December 2011 **Page** 1 **of** 1

Applicant: R. Jacopic **Group:** RM-Nuclear

Project: IRMM-1027 O LSD **IM-unit ref.:**

Description: Preparation mother solution IRMM-1027 O

Date of receipt of request: 12 May 2011 **Weighing date**: 10 October 2011

The reported results applies only to the objects / samples described in this certificate

	Weight in g
Mass of Pu metal (MP 2 BC 2701)	2.2495 (2)
Mass of U metal (NBL-CRM-116)	13.435 (2)
Mass of U metal (EC-NRM-101)	53.507 (6)
Mass of IRMM-1027 O	3143.64 (7)

Observations:

The measurements and uncertainty estimates, were performed according to working instruction WI-0185, "Mass determination by substitution weighing"on balances AT 261 and At 201 with IRMM inventory No 1999 00337 27 and 1996 00547 73 and balance PR 5002 with inventory No. 9800298.

Traceability:

The certified mass values are traceable to the International Kilogram Prototype via regular calibrations of the IRMM principal kilogram. The sets of working mass standards M 3 and M 10 were used as reference in the mass determination.

Uncertainty:

All reported uncertainties are expanded uncertainties $U = k \cdot u_c$ where u_c is the combined standard uncertainty calculated according to the ISO/BIPM Guide to the expression of Uncertainty in Measurement. The coverage factor $k = 2$ corresponds to a coverage probability of about 95%. U applies to the last digit of the value of the measurement result and is given in parentheses ().

Annexes:

Signature
Mass Metrology Service

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Annex 15: Gravimetric mixture for IRMM-1027o - PLUTONIUM

Gravimetric mixture for IRMM-1027o - PLUTONIUM

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A plutonium gravimetric mixture was prepared by dissolving plutonium MP2 metal (CEA/CETAMA) in nitric acid.

Input parameters:

a) Mass of plutonium metal and the nitrate solution (weighing certificate E3788) b) Purity of plutonium metal (metal certificate) c) Plutonium isotope amount ratios (IRMM certificate, issued 11 April 2007) d) Atomic masses for plutonium isotopes from G. Audi et al. Nuclear Physics A729 (2003), 337-676 e) Half-lives from Laboratorie National Henri Becquerel, http://www.nucleide.org/DDEP$_{WG}$/DDEPdata.htm

Purity of MP2 metal on 1 November 2012 was calculated from the the purity on 1 January 2007 (99.875 +/-0.040), which was derived from the original CETAMA certificate (99.90 +/-0.04).

All the data are decayed to 1 November 2012 (reference date)

Model Equation:

{Molar mass of plutonium in MP2, 1 Jan 2007}

$M_{Pu} = M_{238Pu}\cdot f_{238Pu} + M_{239Pu}\cdot f_{239Pu} + M_{240Pu}\cdot f_{240Pu} + M_{241Pu}\cdot f_{241Pu} + M_{242Pu}\cdot f_{242Pu}$;

{Isotope amount fraction in MP2, 1 Jan 2007}

$f_{238Pu} = R_{238Pu/239Pu}/\Sigma R_{Pu}$;

$f_{239Pu} = 1/\Sigma R_{Pu}$;

$f_{240Pu} = R_{240Pu/239Pu}/\Sigma R_{Pu}$;

$f_{241Pu} = R_{241Pu/239Pu}/\Sigma R_{Pu}$;

$f_{242Pu} = R_{242Pu/239Pu}/\Sigma R_{Pu}$;

$\Sigma R_{Pu} = R_{238Pu/239Pu} + 1 + R_{240Pu/239Pu} + R_{241Pu/239Pu} + R_{242Pu/239Pu}$;

{Isotope mass fractios in MP2, 1 Jan 2007}

$w_{238Pu} = f_{238Pu}\cdot M_{238Pu}/M_{Pu}$;

$w_{239Pu} = f_{239Pu}\cdot M_{239Pu}/M_{Pu}$;

$w_{240Pu} = f_{240Pu}\cdot M_{240Pu}/M_{Pu}$;

$w_{241Pu} = f_{241Pu}\cdot M_{241Pu}/M_{Pu}$;

$w_{242Pu} = f_{242Pu}\cdot M_{242Pu}/M_{Pu}$;

{Decayed isotope amount ratios in gravimetric mixture, IRMM-1027o, 1 November 2012}

$Rd_{238Pu/239Pu} = R_{238Pu/239Pu}\cdot(e^{(-\lambda_{238}\cdot\Delta t)}/e^{(-\lambda_{239}\cdot\Delta t)})$;

$Rd_{240Pu/239Pu} = R_{240Pu/239Pu}\cdot(e^{(-\lambda_{240}\cdot\Delta t)}/e^{(-\lambda_{239}\cdot\Delta t)})$;

$Rd_{241Pu/239Pu} = R_{241Pu/239Pu}\cdot(e^{(-\lambda_{241}\cdot\Delta t)}/e^{(-\lambda_{239}\cdot\Delta t)})$;

$Rd_{242Pu/239Pu} = R_{242Pu/239Pu} \cdot (e^{(-\lambda_{242} \cdot \Delta t)}/e^{(-\lambda_{239} \cdot \Delta t)})$;

$\Sigma Rd_{Pu} = Rd_{238Pu/239Pu} + 1 + Rd_{240Pu/239Pu} + Rd_{241Pu/239Pu} + Rd_{242Pu/239Pu}$;

{Decayed and normalised isotope amount fractios in gravimetric mixture, IRMM-1027o, 1 November 2012}

$fdnorm_{238Pu} = Rd_{238Pu/239Pu}/\Sigma Rd_{Pu}$;

$fdnorm_{239Pu} = 1/\Sigma Rd_{Pu}$;

$fdnorm_{240Pu} = Rd_{240Pu/239Pu}/\Sigma Rd_{Pu}$;

$fdnorm_{241Pu} = Rd_{241Pu/239Pu}/\Sigma Rd_{Pu}$;

$fdnorm_{242Pu} = Rd_{242Pu/239Pu}/\Sigma Rd_{Pu}$;

{Decayed molar mass of plutonium in gravimetric mixtures, IRMM-1027o, 1 November 2012}

$Md_{Pu} = M_{238Pu} \cdot fdnorm_{238Pu} + M_{239Pu} \cdot fdnorm_{239Pu} + M_{240Pu} \cdot fdnorm_{240Pu} + M_{241Pu} \cdot fdnorm_{241Pu} + M_{242Pu} \cdot fdnorm_{242Pu}$;

{Decayed and normalised isotope mass fractios in gravimetric mixture, IRMM-1027o, 1 November 2012}

$wdnorm_{238Pu} = fdnorm_{238Pu} \cdot M_{238Pu}/Md_{Pu}$;

$wdnorm_{239Pu} = fdnorm_{239Pu} \cdot M_{239Pu}/Md_{Pu}$;

$wdnorm_{240Pu} = fdnorm_{240Pu} \cdot M_{240Pu}/Md_{Pu}$;

$wdnorm_{241Pu} = fdnorm_{241Pu} \cdot M_{241Pu}/Md_{Pu}$;

$wdnorm_{242Pu} = fdnorm_{242Pu} \cdot M_{242Pu}/Md_{Pu}$;

{Decayed amount ratios for purity calculation, 1 November 2012}

$fd_{238Pu}=f_{238Pu}*e^{(-\lambda_{238}*\Delta t)}$;

$fd_{239Pu}=f_{239Pu}*e^{(-\lambda_{239}*\Delta t)}$;

$fd_{240Pu}=f_{240Pu}*e^{(-\lambda_{240}*\Delta t)}$;

$fd_{241Pu}=f_{241Pu}*e^{(-\lambda_{241}*\Delta t)}$;

$fd_{242Pu}=f_{242Pu}*e^{(-\lambda_{242}*\Delta t)}$;

{Decayed isotope masses for purity calculation, 1 November 2012}

$md_{238Pu}=fd_{238Pu}*M_{238Pu}*m_{Pu}/M_{Pu}$;

$md_{239Pu}=fd_{239Pu}*M_{239Pu}*m_{Pu}/M_{Pu}$;

$md_{240Pu}=fd_{240Pu}*M_{240Pu}*m_{Pu}/M_{Pu}$;

$md_{241Pu}=fd_{241Pu}*M_{241Pu}*m_{Pu}/M_{Pu}$;

$md_{242Pu}=fd_{242Pu}*M_{242Pu}*m_{Pu}/M_{Pu}$;

$\Sigma md_{Pu}= md_{238Pu}+md_{239Pu}+md_{240Pu}+md_{241Pu}+md_{242Pu}$;

$\eta_{Pufinal}=\eta_{PuMP2}*\Sigma md_{Pu}/m_{Pu}$;

{Decay constants}

$ln_2 = ln(2)$;

$\lambda_{238} = ln_2 / \tau_{238}$;

$\lambda_{239} = ln_2 / \tau_{239}$;

$\lambda_{240} = ln_2 / \tau_{240}$;

$\lambda_{241} = ln_2 / \tau_{241}$;

$\lambda_{242} = ln_2 / \tau_{242}$;

{Plutonium mass fraction in gravimetric mixture, IRMM-1027o, 1 November 2012}

$\gamma_{Pumixture}=(m_{PuMP2}*\eta_{Pufinal})/m_{solution1027o}$;

$\gamma_{Pumixture239}=\gamma_{Pumixture}*wdnorm_{239Pu}$;

$m_{239Puvial1}=\gamma_{Pumixture239}*m_{vial1}$;

{Plutonium amount content in gravimetric mixture, IRMM-1027o, 1 November 2012}

$c_{Pumixture}=\gamma_{Pumixture}/Md_{Pu}$;

$c_{Pumixture239} = c_{Pumixture}*fdnorm_{239Pu}$

List of Quantities:

Quantity	Unit	Definition
Δt	a	time difference between certification date MP2 (1 Jan 2007) and reference date (1 November 2012)
$Rd_{238Pu/239Pu}$	mol/mol	decayed $^{238}Pu/^{239}Pu$ amount ratio in IRMM-1027o, 1 November 2012
$Rd_{240Pu/239Pu}$	mol/mol	decayed $^{240}Pu/^{239}Pu$ amount ratio in IRMM-1027o, 1 November 2012
$Rd_{241Pu/239Pu}$	mol/mol	decayed $^{241}Pu/^{239}Pu$ amount ratio in IRMM-1027o, 1 November 2012
$Rd_{242Pu/239Pu}$	mol/mol	decayed $^{242}Pu/^{239}Pu$ amount ratio in IRMM-1027o, 1 November 2012
$R_{238Pu/239Pu}$	mol/mol	$^{238}Pu/^{239}Pu$ amount ratio in MP2, 1 Jan 2007
$R_{240Pu/239Pu}$	mol/mol	$^{240}Pu/^{239}Pu$ amount ratio in MP2, 1 Jan 2007
$R_{241Pu/239Pu}$	mol/mol	$^{241}Pu/^{239}Pu$ amount ratio in MP2, 1 Jan 2007
$R_{242Pu/239Pu}$	mol/mol	$^{242}Pu/^{239}Pu$ amount ratio in MP2, 1 Jan 2007
M_{Pu}	g/mol	molar mass of Pu in MP2, 1 Jan 2007
f_{238Pu}	mol/mol	^{238}Pu amount fraction in MP2, 1 Jan 2007
f_{239Pu}	mol/mol	^{239}Pu amount fraction in MP2, 1 Jan 2007

Quantity	Unit	Definition
f_{240Pu}	mol/mol	^{240}Pu amount fraction in MP2, 1 Jan 2007
f_{241Pu}	mol/mol	^{241}Pu amount fraction in MP2, 1 Jan 2007
f_{242Pu}	mol/mol	^{242}Pu amount fraction in MP2, 1 Jan 2007
e		
ΣR_{Pu}	mol/mol	Sum of amount ratios in MP2, 1 Jan 2007
λ_{238}	a^{-1}	Decay constant ^{238}Pu
λ_{239}	a^{-1}	Decay constant ^{239}Pu
λ_{240}	a^{-1}	Decay constant ^{240}Pu
λ_{241}	a^{-1}	Decay constant ^{241}Pu
λ_{242}	a^{-1}	Decay constant ^{242}Pu
M_{238Pu}	g/mol	Atomic mass of ^{238}Pu
M_{239Pu}	g/mol	Atomic mass of ^{239}Pu
M_{240Pu}	g/mol	Atomic mass of ^{240}Pu
M_{241Pu}	g/mol	Atomic mass of ^{241}Pu
M_{242Pu}	g/mol	Atomic mass of ^{242}Pu
ΣRd_{Pu}	mol/mol	Sum of decayed amount ratios in gravimetric mixture, IRMM-1027o, 1 November 2012
$fdnorm_{238Pu}$	mol/mol	Decayed and normalised ^{238}Pu amount fraction in gravimetric mixture, IRMM-1027o, 1 November 2012
$fdnorm_{239Pu}$	mol/mol	Decayed and normalised ^{239}Pu amount fraction in gravimetric mixture, IRMM-1027o, 1 November 2012
$fdnorm_{240Pu}$	mol/mol	Decayed and normalised ^{240}Pu amount fraction in gravimetric mixture, IRMM-1027o, 1 November 2012
$fdnorm_{241Pu}$	mol/mol	Decayed and normalised ^{241}Pu amount fraction in gravimetric mixture, IRMM-1027o, 1 November 2012
$fdnorm_{242Pu}$	mol/mol	Decayed and normalised ^{242}Pu amount fraction in gravimetric mixture, IRMM-1027o, 1 November 2012
Md_{Pu}	g/mol	Decayed molar mass of Pu in gravimetric mixture, IRMM-1027o, 1 November 2012
$wdnorm_{238Pu}$	g/g	Decayed and normalised ^{238}Pu mass fraction in gravimetric mixture, IRMM-1027o, 1 November 2012
$wdnorm_{239Pu}$	g/g	Decayed and normalised ^{239}Pu mass fraction in gravimetric mixture, IRMM-1027o, 1 November 2012
$wdnorm_{240Pu}$	g/g	Decayed and normalised ^{240}Pu mass fraction in gravimetric mixture, IRMM-1027o, 1 November 2012
$wdnorm_{241Pu}$	g/g	Decayed and normalised ^{241}Pu mass fraction in gravimetric mixture, IRMM-1027o, 1 November 2012
$wdnorm_{242Pu}$	g/g	Decayed and normalised ^{242}Pu mass fraction in gravimetric mixture, IRMM-1027o, 1 November 2012

Quantity	Unit	Definition
$\eta_{Pufinal}$	g/g	Purity of MP2 metal, 1 November 2012
ln_2		
τ_{238}	a	Half-life ^{238}Pu
τ_{239}	a	Half-life ^{239}Pu
τ_{240}	a	Half-life ^{240}Pu
τ_{241}	a	Half-life ^{241}Pu
τ_{242}	a	Half-life ^{242}Pu
$\gamma_{Pumixture}$	g/g	Pu mass fraction in IRMM-127o
m_{PuMP2}	g	Mass of plutonium MP2 metal
$m_{solution1027o}$	g	Mass of gravimetric mixture, IRMM-1027o
$\gamma_{Pumixture239}$	g/g	^{239}Pu mass fraction in IRMM-1027o
$c_{Pumixture}$	mol/g	Pu amount content in IRMM-127o
$c_{Pumixture239}$	mol/g	^{239}Pu amount content in IRMM-1027o
m_{Pu}	g	
md_{238Pu}	g	Decayed mass of ^{238}Pu, from 1 Jan 2007 to 1 November 2012
md_{239Pu}	g	Decayed mass of ^{239}Pu, from 1 Jan 2007 to 1 November 2012
md_{240Pu}	g	Decayed mass of ^{240}Pu, from 1 Jan 2007 to 1 November 2012
md_{241Pu}	g	Decayed mass of ^{241}Pu, from 1 Jan 2007 to 1 November 2012
md_{242Pu}	g	Decayed mass of ^{242}Pu, from 1 Jan 2007 to 1 November 2012
Σmd_{Pu}	g	Sum of decayed Pu masses
η_{PuMP2}	g/g	Purity of MP2 metal, 1 Jan 2007
w_{238Pu}	g/g	^{238}Pu mass fraction in MP2, 1 Jan 2007
w_{239Pu}	g/g	^{239}Pu mass fraction in MP2, 1 Jan 2007
w_{240Pu}	g/g	^{240}Pu mass fraction in MP2, 1 Jan 2007
w_{241Pu}	g/g	^{241}Pu mass fraction in MP2, 1 Jan 2007
w_{242Pu}	g/g	^{242}Pu mass fraction in MP2, 1 Jan 2007
fd_{238Pu}	mol/mol	Decayed ^{238}Pu amount fraction in MP2, from 1 Jan 2007 to 1 November 2012
fd_{239Pu}	mol/mol	Decayed ^{239}Pu amount fraction in MP2, from 1 Jan 2007 to 1 November 2012
fd_{240Pu}	mol/mol	Decayed ^{240}Pu amount fraction in MP2, from 1 Jan 2007 to 1 November 2012
fd_{241Pu}	mol/mol	Decayed ^{241}Pu amount fraction in MP2, from 1 Jan 2007 to 1 November 2012
fd_{242Pu}	mol/mol	Decayed ^{242}Pu amount fraction in MP2, from 1 Jan 2007 to 1 November 2012
$m_{239Puvial1}$		

Quantity	Unit	Definition
m_{vial1}		

Δt: Type B rectangular distribution
Value: 5.83436 a
Halfwidth of Limits: 0.038 a

01/01/2007, 01/11/2012, delta t= 2131 days / 365.25 = 5.83436 a

$R_{238Pu/239Pu}$: Type B normal distribution
Value: 0.00003083 mol/mol
Expanded Uncertainty: 0.00000029 mol/mol
Coverage Factor: 2

IRMM MP2 certificate 2007

$R_{240Pu/239Pu}$: Type B normal distribution
Value: 0.0224324 mol/mol
Expanded Uncertainty: 0.0000051 mol/mol
Coverage Factor: 2

IRMM MP2 certificate 2007

$R_{241Pu/239Pu}$: Type B normal distribution
Value: 0.0002378 mol/mol
Expanded Uncertainty: 0.0000031 mol/mol
Coverage Factor: 2

IRMM MP2 certificate 2007

$R_{242Pu/239Pu}$: Type B normal distribution
Value: 0.00007570 mol/mol
Expanded Uncertainty: 0.00000078 mol/mol
Coverage Factor: 2

IRMM MP2 certificate 2007

e: Constant
Value: 2.71828182845904523536

M_{238Pu}: Type B normal distribution
Value: 238.0495599 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al.,The AME2003 atomic mass evaluation, Nuclear Physics A 729, (2003), 337-676

M_{239Pu}: Type B normal distribution
Value: 239.0521634 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al.,The AME2003 atomic mass evaluation, Nuclear Physics A 729, (2003), 337-676

M_{240Pu}: Type B normal distribution
Value: 240.0538135 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al.,The AME2003 atomic mass evaluation, Nuclear Physics A 729, (2003), 337-676

M_{241Pu}: Type B normal distribution
Value: 241.0568515 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al.,The AME2003 atomic mass evaluation, Nuclear Physics A 729, (2003), 337-676

M_{242Pu}: Type B normal distribution
Value: 242.0587426 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al.,The AME2003 atomic mass evaluation, Nuclear Physics A 729, (2003), 337-676

τ_{238}: Type B normal distribution
Value: 87.74 a
Expanded Uncertainty: 0.03 a
Coverage Factor: 1

Laboratorie National Henri Becquerel, http://www.nucleide.org/$DDEP_{WG}$/DDEPdata.htm

τ_{239}: Type B normal distribution
Value: 24100 a
Expanded Uncertainty: 11 a
Coverage Factor: 1

Laboratorie National Henri Becquerel, http://www.nucleide.org/$DDEP_{WG}$/DDEPdata.htm

τ_{240}: Type B normal distribution
Value: 6561 a
Expanded Uncertainty: 7 a
Coverage Factor: 1

Laboratorie National Henri Becquerel, http://www.nucleide.org/$DDEP_{WG}$/DDEPdata.htm

τ_{241}: Type B normal distribution
Value: 14.325 a
Expanded Uncertainty: 0.024 a
Coverage Factor: 2

Wellum et al., J. Anal. At. Spectrom., 2009, 24, 801-807

τ_{242}: Type B normal distribution
Value: 373000 a
Expanded Uncertainty: 3000 a
Coverage Factor: 1

Laboratorie National Henri Becquerel, http://www.nucleide.org/$DDEP_{WG}$/DDEPdata.htm

m_{PuMP2}: Type B normal distribution
Value: 2.2495 g
Expanded Uncertainty: 0.0002 g
Coverage Factor: 2

weighing certificate E3788

$m_{solution1027o}$: Type B normal distribution
Value: 3143.64 g
Expanded Uncertainty: 0.07 g
Coverage Factor: 2

weighing certificate E3788

m_{Pu}: Type B normal distribution
Value: 1.00 g
Expanded Uncertainty: 0 g
Coverage Factor: 1

η_{PuMP2}: Import
Filename: Decay MP2 from 12-03-2001 to 01-01-2007.smu
Symbol: $\eta_{Pufinal}$

m_{vial1}: Type B normal distribution
Value: 2.5150
Expanded Uncertainty: 0.0006
Coverage Factor: 2

Input Correlation:

The abundance set for Pu is assumed as uncorrelated.

Interim Results:

Quantity	Value	Standard Uncertainty
M_{Pu}	239.07479084 g/mol	$4.49 \cdot 10^{-6}$ g/mol
f_{238Pu}	$30.143 \cdot 10^{-6}$ mol/mol	$142 \cdot 10^{-9}$ mol/mol
f_{239Pu}	0.97773050 mol/mol	$2.88 \cdot 10^{-6}$ mol/mol
f_{240Pu}	0.02193284 mol/mol	$2.44 \cdot 10^{-6}$ mol/mol
f_{241Pu}	$232.50 \cdot 10^{-6}$ mol/mol	$1.52 \cdot 10^{-6}$ mol/mol
f_{242Pu}	$74.014 \cdot 10^{-6}$ mol/mol	$381 \cdot 10^{-9}$ mol/mol
ΣR_{Pu}	1.02277673 mol/mol	$3.01 \cdot 10^{-6}$ mol/mol
λ_{238}	$7.90001 \cdot 10^{-3}$ a^{-1}	$2.70 \cdot 10^{-6}$ a^{-1}
λ_{239}	$28.7613 \cdot 10^{-6}$ a^{-1}	$13.1 \cdot 10^{-9}$ a^{-1}
λ_{240}	$105.647 \cdot 10^{-6}$ a^{-1}	$113 \cdot 10^{-9}$ a^{-1}
λ_{241}	0.0483872 a^{-1}	$40.5 \cdot 10^{-6}$ a^{-1}
λ_{242}	$1.8583 \cdot 10^{-6}$ a^{-1}	$14.9 \cdot 10^{-9}$ a^{-1}
ΣRd_{Pu}	1.02270684 mol/mol	$2.84 \cdot 10^{-6}$ mol/mol
md_{238Pu}	$28.662 \cdot 10^{-6}$ g	$135 \cdot 10^{-9}$ g
md_{239Pu}	0.97747392 g	$2.96 \cdot 10^{-6}$ g
md_{240Pu}	0.02200909 g	$2.45 \cdot 10^{-6}$ g
md_{241Pu}	$176.77 \cdot 10^{-6}$ g	$1.17 \cdot 10^{-6}$ g
md_{242Pu}	$74.937 \cdot 10^{-6}$ g	$386 \cdot 10^{-9}$ g
Σmd_{Pu}	0.999763379 g	$943 \cdot 10^{-9}$ g
w_{238Pu}	$30.014 \cdot 10^{-6}$ g/g	$141 \cdot 10^{-9}$ g/g
w_{239Pu}	0.97763796 g/g	$2.90 \cdot 10^{-6}$ g/g
w_{240Pu}	0.02202266 g/g	$2.45 \cdot 10^{-6}$ g/g
w_{241Pu}	$234.43 \cdot 10^{-6}$ g/g	$1.53 \cdot 10^{-6}$ g/g
w_{242Pu}	$74.938 \cdot 10^{-6}$ g/g	$386 \cdot 10^{-9}$ g/g
fd_{238Pu}	$28.786 \cdot 10^{-6}$ mol/mol	$135 \cdot 10^{-9}$ mol/mol
fd_{239Pu}	0.97756644 mol/mol	$2.95 \cdot 10^{-6}$ mol/mol
fd_{240Pu}	0.02191933 mol/mol	$2.44 \cdot 10^{-6}$ mol/mol
fd_{241Pu}	$175.32 \cdot 10^{-6}$ mol/mol	$1.16 \cdot 10^{-6}$ mol/mol
fd_{242Pu}	$74.013 \cdot 10^{-6}$ mol/mol	$381 \cdot 10^{-9}$ mol/mol

Uncertainty Budgets:

$Rd_{238Pu/239Pu}$: decayed $^{238}Pu/^{239}Pu$ amount ratio in IRMM-1027o, 1 November 2012

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
Δt	5.8344 a	0.0219 a	rectangular	$-230 \cdot 10^{-9}$	$-5.1 \cdot 10^{-9}$ mol/mol	0.1 %
$R_{238Pu/239Pu}$	$30.830 \cdot 10^{-6}$ mol/mol	$145 \cdot 10^{-9}$ mol/mol	normal	0.96	$140 \cdot 10^{-9}$ mol/mol	99.9 %
$Rd_{238Pu/239Pu}$	$29.446 \cdot 10^{-6}$ mol/mol	$139 \cdot 10^{-9}$ mol/mol				

$Rd_{240Pu/239Pu}$: decayed $^{240}Pu/^{239}Pu$ amount ratio in IRMM-1027o, 1 November 2012

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$R_{240Pu/239Pu}$	0.02243240 mol/mol	$2.55 \cdot 10^{-6}$ mol/mol	normal	1.0	$2.5 \cdot 10^{-6}$ mol/mol	100.0 %
$Rd_{240Pu/239Pu}$	0.02242234 mol/mol	$2.55 \cdot 10^{-6}$ mol/mol				

$Rd_{241Pu/239Pu}$: decayed $^{241}Pu/^{239}Pu$ amount ratio in IRMM-1027o, 1 November 2012

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
Δt	5.8344 a	0.0219 a	rectangular	$-8.7 \cdot 10^{-6}$	$-190 \cdot 10^{-9}$ mol/mol	2.6 %
$R_{241Pu/239Pu}$	$237.80 \cdot 10^{-6}$ mol/mol	$1.55 \cdot 10^{-6}$ mol/mol	normal	0.75	$1.2 \cdot 10^{-6}$ mol/mol	97.3 %
τ_{241}	14.3250 a	0.0120 a	normal	$3.5 \cdot 10^{-6}$	$42 \cdot 10^{-9}$ mol/mol	0.1 %
$Rd_{241Pu/239Pu}$	$179.34 \cdot 10^{-6}$ mol/mol	$1.19 \cdot 10^{-6}$ mol/mol				

$Rd_{242Pu/239Pu}$: decayed $^{242}Pu/^{239}Pu$ amount ratio in IRMM-1027o, 1 November 2012

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$R_{242Pu/239Pu}$	$75.700 \cdot 10^{-6}$ mol/mol	$390 \cdot 10^{-9}$ mol/mol	normal	1.0	$390 \cdot 10^{-9}$ mol/mol	100.0 %
$Rd_{242Pu/239Pu}$	$75.712 \cdot 10^{-6}$ mol/mol	$390 \cdot 10^{-9}$ mol/mol				

$\eta_{Pufinal}$: **Purity of MP2 metal, 1 November 2012**

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
η_{PuMP2}	0.998746 g/g	$200 \cdot 10^{-6}$ g/g		1.0	$200 \cdot 10^{-6}$ g/g	100.0 %
$\eta_{Pufinal}$	0.998510 g/g	$200 \cdot 10^{-6}$ g/g				

$\gamma_{Pumixture239}$: **^{239}Pu mass fraction in IRMM-1027o**

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
m_{PuMP2}	2.249500 g	$100 \cdot 10^{-6}$ g	normal	$310 \cdot 10^{-6}$	$31 \cdot 10^{-9}$ g/g	4.7 %
$m_{solution1027o}$	3143.6400 g	0.0350 g	normal	0.0	$-7.8 \cdot 10^{-9}$ g/g	0.3 %
η_{PuMP2}	0.998746 g/g	$200 \cdot 10^{-6}$ g/g		$700 \cdot 10^{-6}$	$140 \cdot 10^{-9}$ g/g	95.0 %
$\gamma_{Pumixture239}$	$698.576 \cdot 10^{-6}$ g/g	$143 \cdot 10^{-9}$ g/g				

$m_{239Puvial1}$:

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
m_{PuMP2}	2.249500 g	$100 \cdot 10^{-6}$ g	normal	$780 \cdot 10^{-6}$	$78 \cdot 10^{-9}$	3.5 %
$m_{solution1027o}$	3143.6400 g	0.0350 g	normal	0.0	$-20 \cdot 10^{-9}$	0.2 %
η_{PuMP2}	0.998746 g/g	$200 \cdot 10^{-6}$ g/g		$1.8 \cdot 10^{-3}$	$350 \cdot 10^{-9}$	71.0 %
m_{vial1}	2.515000	$300 \cdot 10^{-6}$	normal	$700 \cdot 10^{-6}$	$210 \cdot 10^{-9}$	25.2 %
$m_{239Puvial1}$	$1.756918 \cdot 10^{-3}$	$417 \cdot 10^{-9}$				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
$Rd_{238Pu/239Pu}$	$29.45 \cdot 10^{-6}$ mol/mol	$280 \cdot 10^{-9}$ mol/mol	2.00	manual
$Rd_{240Pu/239Pu}$	0.0224223 mol/mol	$5.1 \cdot 10^{-6}$ mol/mol	2.00	manual
$Rd_{241Pu/239Pu}$	$179.3 \cdot 10^{-6}$ mol/mol	$2.4 \cdot 10^{-6}$ mol/mol	2.00	manual
$Rd_{242Pu/239Pu}$	$75.71 \cdot 10^{-6}$ mol/mol	$780 \cdot 10^{-9}$ mol/mol	2.00	manual
$fdnorm_{238Pu}$	$28.79 \cdot 10^{-6}$ mol/mol	$270 \cdot 10^{-9}$ mol/mol	2.00	manual
$fdnorm_{239Pu}$	0.9777973 mol/mol	$5.4 \cdot 10^{-6}$ mol/mol	2.00	manual
$fdnorm_{240Pu}$	0.0219245 mol/mol	$4.9 \cdot 10^{-6}$ mol/mol	2.00	manual
$fdnorm_{241Pu}$	$175.4 \cdot 10^{-6}$ mol/mol	$2.3 \cdot 10^{-6}$ mol/mol	2.00	manual
$fdnorm_{242Pu}$	$74.03 \cdot 10^{-6}$ mol/mol	$760 \cdot 10^{-9}$ mol/mol	2.00	manual
Md_{Pu}	239.0746693 g/mol	$8.1 \cdot 10^{-6}$ g/mol	2.00	manual
$wdnorm_{238Pu}$	$28.67 \cdot 10^{-6}$ g/g	$270 \cdot 10^{-9}$ g/g	2.00	manual
$wdnorm_{239Pu}$	0.9777053 g/g	$5.5 \cdot 10^{-6}$ g/g	2.00	manual
$wdnorm_{240Pu}$	0.0220143 g/g	$4.9 \cdot 10^{-6}$ g/g	2.00	manual
$wdnorm_{241Pu}$	$176.8 \cdot 10^{-6}$ g/g	$2.3 \cdot 10^{-6}$ g/g	2.00	manual
$wdnorm_{242Pu}$	$74.95 \cdot 10^{-6}$ g/g	$770 \cdot 10^{-9}$ g/g	2.00	manual
$\eta_{Pufinal}$	0.99851 g/g	$400 \cdot 10^{-6}$ g/g	2.00	manual
$\gamma_{Pumixture}$	$714.51 \cdot 10^{-6}$ g/g	$290 \cdot 10^{-9}$ g/g	2.00	manual
$\gamma_{Pumixture239}$	$698.58 \cdot 10^{-6}$ g/g	$290 \cdot 10^{-9}$ g/g	2.00	manual
$c_{Pumixture}$	$2.9886 \cdot 10^{-6}$ mol/g	$1.2 \cdot 10^{-9}$ mol/g	2.00	manual
$c_{Pumixture239}$	$2.9223 \cdot 10^{-6}$ mol/g	$1.2 \cdot 10^{-9}$ mol/g	2.00	manual
$m_{239Puvial1}$	$1.75692 \cdot 10^{-3}$	$830 \cdot 10^{-9}$	2.00	manual

Annex 16: Gravimetric mixture for IRMM-1027o – URANIUM

Gravimetric mixture for IRMM-1027o - URANIUM

Author: Rozle Jakopic

A uranium gravimetric mixture was prepared by dissolving natural uranium (EC NRM 101) and enriched uranium (NBL CRM-116) metals in nitric acid solution.

Input parameters: a) masses of the metals and the mother solution (weighing certificate, E3788) b) purity of the metals (metal certificates) c) uranium isotope amount ratios of the metals (certificate) d) atomic masses for uranium isotopes from G. Audi et al., Nuclear Physics A 729 (2003), 337-676.

Model Equation:

{Molar mass of uranium in gravimetric mixture, IRMM-1027o}

$M_U = M_{233U} \cdot f_{233U} + M_{234U} \cdot f_{234U} + M_{235U} \cdot f_{235U} + M_{236U} \cdot f_{236U} + M_{238U} \cdot f_{238U}$;

{Isotope amount fraction in gravimetric mixture, IRMM-1027o}

$f_{233U} = R_{233U/238U} / \Sigma R_U$;

$f_{234U} = R_{234U/238U} / \Sigma R_U$;

$f_{235U} = R_{235U/238U} / \Sigma R_U$;

$f_{236U} = R_{236U/238U} / \Sigma R_U$;

$f_{238U} = 1 / \Sigma R_U$;

$\Sigma R_U = R_{233U/238U} + R_{234U/238U} + R_{235U/238U} + R_{236U/238U} + 1$;

{Isotope mass fraction in gravimetric mixture, IRMM-1027o}

$w_{233U} = f_{233U} \cdot M_{233U} / M_U$;

$w_{234U} = f_{234U} \cdot M_{234U} / M_U$;

$w_{235U} = f_{235U} \cdot M_{235U} / M_U$;

$w_{236U} = f_{236U} \cdot M_{236U} / M_U$;

$w_{238U} = f_{238U} \cdot M_{238U} / M_U$;

{Isotope amount ratios in gravimetric mixture, IRMM-1027o}

$R_{233U/238U} = n_{233U} / n_{238U}$;

$R_{234U/238U} = n_{234U} / n_{238U}$;

$R_{235U/238U} = n_{235U} / n_{238U}$;

$R_{236U/238U} = n_{236U} / n_{238U}$;

{Amount of uranium isotopes in gravimetric mixture, IRMM-1027o}

$n_{233U} = (n_{233.a} + n_{233.b})$;

$n_{234U} = (n_{234.a} + n_{234.b})$;

$n_{235U} = (n_{235.a} + n_{235.b})$;

$n_{236U} = (n_{236.a} + n_{236.b})$;

$n_{238U} = (n_{238.a} + n_{238.b})$;

{uranium mass fraction in gravimetric mixture, IRMM-1027o}

$\gamma_{Umixture}=(m_{UCRM116}*\eta_{purityCRM116}+m_{UEC101}*\eta_{purityEC101})/m_{solution1027o}$;

$\gamma_{235Umixture}=\gamma_{Umixture}*w_{235U}$;

$\gamma_{238Umixture}=\gamma_{Umixture}*w_{238U}$;

$m_{235Uvial1}=\gamma_{235Umixture}*m_{aliquot1}$;

$m_{238Uvial1}=\gamma_{238Umixture}*m_{aliquot1}$;

{uranium amount content in gravimetric mixture, IRMM-1027o}

$c_{Umixture}=\gamma_{Umixture}/M_U$;

$c_{235Umixture}=c_{Umixture}*f_{235U}$;

$c_{238Umixture}=c_{Umixture}*f_{238U}$;

{Amount of uranium isotopes in EC NRM 101}

$n_{233.a} = m_{UEC101} *\eta_{purityEC101} * f_{233Ua} / M_{Ua}$;

$n_{234.a} = m_{UEC101} *\eta_{purityEC101} * f_{234Ua} / M_{Ua}$;

$n_{235.a} = m_{UEC101} *\eta_{purityEC101} * f_{235Ua} / M_{Ua}$;

$n_{236.a} = m_{UEC101} *\eta_{purityEC101} * f_{236Ua} / M_{Ua}$;

$n_{238.a} = m_{UEC101} *\eta_{purityEC101} * f_{238Ua} / M_{Ua}$;

{Amount of uranium isotopes in NBL CRM-116}

$n_{233.b} = m_{UCRM116} *\eta_{purityCRM116} * f_{233Ub} / M_{Ub}$;

$n_{234.b} = m_{UCRM116} *\eta_{purityCRM116} * f_{234Ub} / M_{Ub}$;

$n_{235.b} = m_{UCRM116} *\eta_{purityCRM116} * f_{235Ub} / M_{Ub}$;

$n_{236.b} = m_{UCRM116} *\eta_{purityCRM116} * f_{236Ub} / M_{Ub}$;

$n_{238.b} = m_{UCRM116} *\eta_{purityCRM116} * f_{238Ub} / M_{Ub}$;

{Isotope amount fraction of uranium in EC NRM 101}

$f_{233Ua} = R_{233U/238Ua}/\Sigma R_{Ua}$;

$f_{234Ua} = R_{234U/238Ua}/\Sigma R_{Ua}$;

$f_{235Ua} = R_{235U/238Ua}/\Sigma R_{Ua}$;

$f_{236Ua} = R_{236U/238Ua}/\Sigma R_{Ua}$;

$f_{238Ua} = 1/\Sigma R_{Ua}$;

$\Sigma R_{Ua} = R_{233U/238Ua} + R_{234U/238Ua} + R_{235U/238Ua} + R_{236U/238Ua} + 1$;

{Molar mass of uranium in EC NRM 101}

$M_{Ua} = M_{233U} \cdot f_{233Ua} + M_{234U} \cdot f_{234Ua} + M_{235U} \cdot f_{235Ua} + M_{236U} \cdot f_{236Ua} + M_{238U} \cdot f_{238Ua}$;

{Isotope amount fraction of uranium n NBL CRM-116}

$f_{233Ub} = R_{233U/235Ub} / \Sigma R_{Ub}$;

$f_{234Ub} = R_{234U/235Ub} / \Sigma R_{Ub}$;

$f_{238Ub} = R_{238U/235Ub} / \Sigma R_{Ub}$;

$f_{236Ub} = R_{236U/235Ub} / \Sigma R_{Ub}$;

$f_{235Ub} = 1 / \Sigma R_{Ub}$;

$\Sigma R_{Ub} = R_{233U/235Ub} + R_{234U/235Ub} + R_{238U/235Ub} + R_{236U/235Ub} + 1$;

{Molar mass of uranium in NBL CRM-116}

$M_{Ub} = M_{233U} \cdot f_{233Ub} + M_{234U} \cdot f_{234Ub} + M_{235U} \cdot f_{235Ub} + M_{236U} \cdot f_{236Ub} + M_{238U} \cdot f_{238Ub}$;

List of Quantities:

Quantity	Unit	Definition
$\gamma_{Umixture}$	g/g	U mass fraction in IRMM-1027o
$\gamma_{235Umixture}$	g/g	^{235}U mass fraction in IRMM-1027o
$\gamma_{238Umixture}$	g/g	^{238}U mass fraction in IRMM-1027o
$c_{Umixture}$	mol/g	U amount content in IRMM-1027o
$c_{235Umixture}$	mol/g	^{235}U amount content in IRMM-1027o
$c_{238Umixture}$	mol/g	^{238}U amount content in IRMM-1027o
M_U	g/mol	Molar mass of U in IRMM-1027o
$R_{233U/238U}$	mol/mol	^{233}U/^{238}U amount ratio in IRMM-1027o
$R_{234U/238U}$	mol/mol	^{234}U/^{238}U amount ratio in IRMM-1027o
$R_{235U/238U}$	mol/mol	^{235}U/^{238}U amount ratio in IRMM-1027o
$R_{236U/238U}$	mol/mol	^{236}U/^{238}U amount ratio in IRMM-1027o
f_{233U}	mol/mol	^{233}U amount fraction in IRMM-1027o
f_{234U}	mol/mol	^{234}U amount fraction in IRMM-1027o
f_{235U}	mol/mol	^{235}U amount fraction in IRMM-1027o
f_{236U}	mol/mol	^{236}U amount fraction in IRMM-1027o
f_{238U}	mol/mol	^{238}U amount fraction in IRMM-1027o
w_{233U}	g/g	^{233}U mass fraction in IRMM-1027o
w_{234U}	g/g	^{234}U mass fraction in IRMM-1027o
w_{235U}	g/g	^{235}U mass fraction in IRMM-1027o
w_{236U}	g/g	^{236}U mass fraction in IRMM-1027o

Quantity	Unit	Definition
w_{238U}	g/g	^{238}U mass fraction in IRMM-1027o
n_{233U}	mol	Amount of U-233 in the mixture
n_{234U}	mol	Amount of U-234 in the mixture
n_{235U}	mol	Amount of U-235 in the mixture
n_{236U}	mol	Amount of U-236 in the mixture
n_{238U}	mol	Amount of U-238 in the mixture
M_{233U}	g/mol	Atomic mass of ^{233}U
M_{234U}	g/mol	Atomic mass of ^{234}U
M_{235U}	g/mol	Atomic mass of ^{235}U
M_{236U}	g/mol	Atomic mass of ^{236}U
M_{238U}	g/mol	Atomic mass of ^{238}U
$m_{solution1027o}$	g	Mass of gravimetric mixture, IRMM-1027o
m_{UEC101}	g	Mass of natural uranium metal, EC-NRM 101
$\eta_{purityEC101}$	g/g	Purity of natural uranium metal, EC NRM 101
$m_{UCRM116}$	g	Mass of enriched uranium metal, NBL CRM-116
$\eta_{purityCRM116}$	g/g	Purity of enriched uranium metal, NBL CRM-116
M_{Ua}	g/mol	Molar mass of U in EC NRM 101
f_{233Ua}		^{233}U amount fraction in EC NRM 101
f_{234Ua}		^{234}U amount fraction in EC NRM 101
f_{235Ua}		^{235}U amount fraction in EC NRM 101
f_{236Ua}		^{236}U amount fraction in EC NRM 101
f_{238Ua}		^{238}U amount fraction in EC NRM 101
M_{Ub}	g/mol	Molar mass of U in NBL CRM-116
f_{233Ub}		^{233}U amount fraction in NBL CRM-116
f_{234Ub}		^{234}U amount fraction in NBL CRM-116
f_{235Ub}		^{235}U amount fraction in NBL CRM-116
f_{236Ub}		^{236}U amount fraction in NBL CRM-116
f_{238Ub}		^{238}U amount fraction in NBL CRM-116
$n_{233.a}$	mol	^{233} U amount in EC NRM 101
$n_{234.a}$	mol	^{234} U amount in EC NRM 101
$n_{235.a}$	mol	^{235} U amount in EC NRM 101
$n_{236.a}$	mol	^{236} U amount in EC NRM 101
$n_{238.a}$	mol	^{238} U amount in EC NRM 101
$n_{233.b}$	mol	^{233} U amount in NBL CRM-116
$n_{234.b}$	mol	^{234} U amount in NBL CRM-116

Quantity	Unit	Definition
$n_{235.b}$	mol	^{235} U amount in NBL CRM-116
$n_{236.b}$	mol	^{236} U amount in NBL CRM-116
$n_{238.b}$	mol	^{238} U amount in NBL CRM-116
$R_{233U/238Ua}$	mol/mol	$^{233}U/^{238}U$ amount ratio in EC NRM 101
$R_{234U/238Ua}$	mol/mol	$^{234}U/^{238}U$ amount ratio in EC NRM 101
$R_{235U/238Ua}$	mol/mol	$^{235}U/^{238}U$ amount ratio in EC NRM 101
$R_{236U/238Ua}$	mol/mol	$^{236}U/^{238}U$ amount ratio in EC NRM 101
$R_{233U/235Ub}$	mol/mol	$^{233}U/^{235}U$ amount ratio in NBL CRM-116
$R_{234U/235Ub}$	mol/mol	$^{234}U/^{235}U$ amount ratio in NBL CRM-116
$R_{238U/235Ub}$	mol/mol	$^{238}U/^{235}U$ amount ratio in NBL CRM-116
$R_{236U/235Ub}$	mol/mol	$^{236}U/^{235}U$ amount ratio in NBL CRM-116
ΣR_U	mol/mol	Sum of amount ratios in gravimteric mixture, IRMM-1027o
ΣR_{Ua}	mol/mol	Sum of amount ratios in EC- NRM 101
ΣR_{Ub}	mol/mol	Sum of amount ratios in NBL CRM-116
$m_{235Uvial1}$	g	^{235}U mass in vial No 1
$m_{aliquot1}$	g	mass of an aliquot in vial No 1 (dispensed mass)
$m_{238Uvial1}$	g	238U mass in vial No 1

M_{233U}: Type B normal distribution
Value: 233.0396352 g/mol
Expanded Uncertainty: 0.0000058 g/mol
Coverage Factor: 2

G. Audi et al., The AME2003 atomic mass evaluation, Nuclear Physics A 729 (2003), 337-676

M_{234U}: Type B normal distribution
Value: 234.0409521 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al., The AME2003 atomic mass evaluation, Nuclear Physics A 729 (2003), 337-676

M_{235U}: Type B normal distribution
Value: 235.0439299 g/mol
Expanded Uncertainty: 0.00000040 g/mol
Coverage Factor: 2

G. Audi et al., The AME2003 atomic mass evaluation, Nuclear Physics A 729 (2003), 337-676

M_{236U}: Type B normal distribution
Value: 236.0455680 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al., The AME2003 atomic mass evaluation, Nuclear Physics A 729 (2003), 337-676

M_{238U}: Type B normal distribution
Value: 238.0507882 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al., The AME2003 atomic mass evaluation, Nuclear Physics A 729 (2003), 337-676

$m_{solution1027o}$: Type B normal distribution
Value: 3143.64 g
Expanded Uncertainty: 0.07 g
Coverage Factor: 2

Weighing certificate E3788

m_{UEC101}: Type B normal distribution
Value: 53.507 g
Expanded Uncertainty: 0.006 g
Coverage Factor: 2

Weighing certificate E3788

$\eta_{purityEC101}$: Type B normal distribution
Value: 0.99985 g/g
Expanded Uncertainty: 0.00005 g/g
Coverage Factor: 2

EC NRM 101 certificate

$m_{UCRM116}$: Type B normal distribution
Value: 13.435 g
Expanded Uncertainty: 0.002 g
Coverage Factor: 2

Weighing certificate E3788

$\eta_{purityCRM116}$: Type B normal distribution
Value: 0.999672 g/g
Expanded Uncertainty: 0.000069 g/g
Coverage Factor: 2

NBL CRM-116 certificate

$R_{233U/238Ua}$: Type B normal distribution
Value: 0 mol/mol
Expanded Uncertainty: 0 mol/mol
Coverage Factor: 1

Certificate of isotopic coposition (IRMM, W. De Bolle)

$R_{234U/238Ua}$: Type B normal distribution
Value: 0.00005548 mol/mol
Expanded Uncertainty: 0.00000022 mol/mol
Coverage Factor: 2

Certificate of isotopic coposition (IRMM, W. De Bolle)

$R_{235U/238Ua}$: Type B normal distribution
Value: 0.0072593 mol/mol
Expanded Uncertainty: 0.0000036 mol/mol
Coverage Factor: 2

Certificate of isotopic coposition (IRMM, W. De Bolle)

$R_{236U/238Ua}$: Type B normal distribution
Value: 0.000000151 mol/mol
Expanded Uncertainty: 0.000000040 mol/mol
Coverage Factor: 2

Certificate of isotopic coposition (IRMM, W. De Bolle)

$R_{233U/235Ub}$: Type B normal distribution
Value: 0 mol/mol
Expanded Uncertainty: 0 mol/mol
Coverage Factor: 1

IRMM measurements, Report of Analysis 2731

$R_{234U/235Ub}$: Type B normal distribution
Value: 0.0106853 mol/mol
Expanded Uncertainty: 0.0000011 mol/mol
Coverage Factor: 2

IRMM measurements, Report of Analysis 2731

$R_{238U/235Ub}$: Type B normal distribution
Value: 0.057975 mol/mol
Expanded Uncertainty: 0.000017 mol/mol
Coverage Factor: 2

IRMM measurements, Report of Analysis 2731

$R_{236U/235Ub}$: Type B normal distribution
Value: 0.00448811 mol/mol
Expanded Uncertainty: 0.00000046 mol/mol
Coverage Factor: 2

IRMM measurements, Report of Analysis 2731

$m_{aliquot1}$: Type B normal distribution
Value: 2.5150 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

Interim Results:

Quantity	Value	Standard Uncertainty
n_{234U}	$580.9488 \cdot 10^{-6}$ mol	$60.3 \cdot 10^{-9}$ mol
n_{235U}	0.05483020 mol	$4.41 \cdot 10^{-6}$ mol
n_{236U}	$238.8481 \cdot 10^{-6}$ mol	$23.6 \cdot 10^{-9}$ mol
n_{238U}	0.2262110 mol	$13.7 \cdot 10^{-6}$ mol
M_{Ua}	238.02889787 g/mol	$5.71 \cdot 10^{-6}$ g/mol
f_{234Ua}	$55.077 \cdot 10^{-6}$	$109 \cdot 10^{-9}$
f_{235Ua}	$7.20658 \cdot 10^{-3}$	$1.77 \cdot 10^{-6}$
f_{236Ua}	$149.9 \cdot 10^{-9}$	$19.9 \cdot 10^{-9}$
f_{238Ua}	0.99273819	$1.78 \cdot 10^{-6}$
M_{Ub}	235.2005727 g/mol	$22.6 \cdot 10^{-6}$ g/mol
f_{234Ub}	$9.956964 \cdot 10^{-3}$	$514 \cdot 10^{-9}$
f_{235Ub}	0.93183756	$7.40 \cdot 10^{-6}$
f_{236Ub}	$4.182189 \cdot 10^{-3}$	$216 \cdot 10^{-9}$
f_{238Ub}	0.05402328	$7.49 \cdot 10^{-6}$
$n_{234.a}$	$12.3790 \cdot 10^{-6}$ mol	$24.6 \cdot 10^{-9}$ mol
$n_{235.a}$	$1.619740 \cdot 10^{-3}$ mol	$411 \cdot 10^{-9}$ mol
$n_{236.a}$	$33.69 \cdot 10^{-9}$ mol	$4.46 \cdot 10^{-9}$ mol
$n_{238.a}$	0.2231262 mol	$13.7 \cdot 10^{-6}$ mol
$n_{234.b}$	$568.5698 \cdot 10^{-6}$ mol	$55.1 \cdot 10^{-9}$ mol
$n_{235.b}$	0.05321046 mol	$4.39 \cdot 10^{-6}$ mol
$n_{236.b}$	$238.8144 \cdot 10^{-6}$ mol	$23.2 \cdot 10^{-9}$ mol
$n_{238.b}$	$3.084877 \cdot 10^{-3}$ mol	$497 \cdot 10^{-9}$ mol
ΣR_U	1.2460092 mol/mol	$24.3 \cdot 10^{-6}$ mol/mol
ΣR_{Ua}	1.00731493 mol/mol	$1.80 \cdot 10^{-6}$ mol/mol
ΣR_{Ub}	1.07314841 mol/mol	$8.52 \cdot 10^{-6}$ mol/mol

Uncertainty Budgets:

$\gamma_{235Umixture}$: ^{235}U mass fraction in IRMM-1027o

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$m_{solution1027o}$	3143.6400 g	0.0350 g	normal	$-1.3 \cdot 10^{-6}$	$-46 \cdot 10^{-9}$ g/g	1.9 %
$m_{UCRM116}$	13.43500 g	$1.00 \cdot 10^{-3}$ g	normal	$300 \cdot 10^{-6}$	$300 \cdot 10^{-9}$ g/g	79.3 %
$\eta_{purityCRM116}$	0.9996720 g/g	$34.5 \cdot 10^{-6}$ g/g	normal	$4.0 \cdot 10^{-3}$	$140 \cdot 10^{-9}$ g/g	17.0 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	0.017	$30 \cdot 10^{-9}$ g/g	0.8 %
$R_{238U/235Ub}$	0.05797500 mol/mol	$8.50 \cdot 10^{-6}$ mol/mol	normal	$-3.8 \cdot 10^{-3}$	$-32 \cdot 10^{-9}$ g/g	0.9 %
$\gamma_{235Umixture}$	$4.099549 \cdot 10^{-3}$ g/g	$333 \cdot 10^{-9}$ g/g				

$\gamma_{238Umixture}$: ^{238}U mass fraction in IRMM-1027o

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$m_{solution1027o}$	3143.6400 g	0.0350 g	normal	$-5.4 \cdot 10^{-6}$	$-190 \cdot 10^{-9}$ g/g	3.3 %
m_{UEC101}	53.50700 g	$3.00 \cdot 10^{-3}$ g	normal	$320 \cdot 10^{-6}$	$950 \cdot 10^{-9}$ g/g	80.5 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	0.017	$420 \cdot 10^{-9}$ g/g	16.0 %
$\gamma_{238Umixture}$	0.01712973 g/g	$1.06 \cdot 10^{-6}$ g/g				

$R_{234U/238U}$: $^{234}U/^{238}U$ amount ratio in IRMM-1027o

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
m_{UEC101}	53.50700 g	$3.00 \cdot 10^{-3}$ g	normal	$-46 \cdot 10^{-6}$	$-140 \cdot 10^{-9}$ mol/mol	20.7 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	$-2.5 \cdot 10^{-3}$	$-62 \cdot 10^{-9}$ mol/mol	4.1 %
$m_{UCRM116}$	13.43500 g	$1.00 \cdot 10^{-3}$ g	normal	$180 \cdot 10^{-6}$	$180 \cdot 10^{-9}$ mol/mol	36.4 %
$\eta_{purityCRM116}$	0.9996720 g/g	$34.5 \cdot 10^{-6}$ g/g	normal	$2.5 \cdot 10^{-3}$	$86 \cdot 10^{-9}$ mol/mol	7.8 %
$R_{234U/238Ua}$	$55.480 \cdot 10^{-6}$ mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	0.99	$110 \cdot 10^{-9}$ mol/mol	12.7 %
$R_{234U/235Ub}$	0.010685300 mol/mol	$550 \cdot 10^{-9}$ mol/mol	normal	0.23	$130 \cdot 10^{-9}$ mol/mol	17.6 %
$R_{238U/235Ub}$	0.05797500 mol/mol	$8.50 \cdot 10^{-6}$ mol/mol	normal	$-2.9 \cdot 10^{-3}$	$-25 \cdot 10^{-9}$ mol/mol	0.7 %
$R_{234U/238U}$	$2.568172 \cdot 10^{-3}$ mol/mol	$306 \cdot 10^{-9}$ mol/mol				

$R_{235U/238U}$: $^{235}U/^{238}U$ amount ratio in IRMM-1027o

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
m_{UEC101}	53.50700 g	$3.00 \cdot 10^{-3}$ g	normal	$-4.3 \cdot 10^{-3}$	$-13 \cdot 10^{-6}$ mol/mol	29.4 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	-0.23	$-5.8 \cdot 10^{-6}$ mol/mol	5.8 %
$m_{UCRM116}$	13.43500 g	$1.00 \cdot 10^{-3}$ g	normal	0.017	$17 \cdot 10^{-6}$ mol/mol	51.8 %
$\eta_{purityCRM116}$	0.9996720 g/g	$34.5 \cdot 10^{-6}$ g/g	normal	0.23	$8.0 \cdot 10^{-6}$ mol/mol	11.1 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	1.2	$2.2 \cdot 10^{-6}$ mol/mol	0.8 %
$R_{238U/235Ub}$	0.05797500 mol/mol	$8.50 \cdot 10^{-6}$ mol/mol	normal	-0.28	$-2.3 \cdot 10^{-6}$ mol/mol	1.0 %
$R_{235U/238U}$	0.2423852 mol/mol	$24.0 \cdot 10^{-6}$ mol/mol				

$R_{236U/238U}$: $^{236}U/^{238}U$ amount ratio in IRMM-1027o

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
m_{UEC101}	53.50700 g	$3.00 \cdot 10^{-3}$ g	normal	$-19 \cdot 10^{-6}$	$-58 \cdot 10^{-9}$ mol/mol	23.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	$-1.0 \cdot 10^{-3}$	$-26 \cdot 10^{-9}$ mol/mol	4.6 %
$m_{UCRM116}$	13.43500 g	$1.00 \cdot 10^{-3}$ g	normal	$78 \cdot 10^{-6}$	$78 \cdot 10^{-9}$ mol/mol	40.6 %
$\eta_{purityCRM116}$	0.9996720 g/g	$34.5 \cdot 10^{-6}$ g/g	normal	$1.0 \cdot 10^{-3}$	$36 \cdot 10^{-9}$ mol/mol	8.7 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	0.99	$20 \cdot 10^{-9}$ mol/mol	2.6 %
$R_{238U/235Ub}$	0.05797500 mol/mol	$8.50 \cdot 10^{-6}$ mol/mol	normal	$-1.2 \cdot 10^{-3}$	$-10 \cdot 10^{-9}$ mol/mol	0.7 %
$R_{236U/235Ub}$	$4.488110 \cdot 10^{-3}$ mol/mol	$230 \cdot 10^{-9}$ mol/mol	normal	0.23	$54 \cdot 10^{-9}$ mol/mol	19.6 %
$R_{236U/238U}$	$1.055864 \cdot 10^{-3}$ mol/mol	$122 \cdot 10^{-9}$ mol/mol				

$m_{235Uvial1}$: ^{235}U mass in vial No 1

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$m_{solution1027o}$	3143.6400 g	0.0350 g	normal	$-3.3 \cdot 10^{-6}$	$-110 \cdot 10^{-9}$ g	0.6 %
$m_{UCRM116}$	13.43500 g	$1.00 \cdot 10^{-3}$ g	normal	$740 \cdot 10^{-6}$	$740 \cdot 10^{-9}$ g	25.1 %
$\eta_{purityCRM116}$	0.9996720 g/g	$34.5 \cdot 10^{-6}$ g/g	normal	0.010	$350 \cdot 10^{-9}$ g	5.4 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	0.042	$75 \cdot 10^{-9}$ g	0.3 %
$R_{238U/235Ub}$	0.05797500 mol/mol	$8.50 \cdot 10^{-6}$ mol/mol	normal	$-9.4 \cdot 10^{-3}$	$-80 \cdot 10^{-9}$ g	0.3 %
$m_{aliquot1}$	2.515000 g	$300 \cdot 10^{-6}$ g	normal	$4.1 \cdot 10^{-3}$	$1.2 \cdot 10^{-6}$ g	68.4 %
$m_{235Uvial1}$	0.01031037 g	$1.49 \cdot 10^{-6}$ g				

$m_{238Uvial1}$: **238U mass in vial No 1**

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$m_{solution1027o}$	3143.6400 g	0.0350 g	normal	$-14 \cdot 10^{-6}$	$-480 \cdot 10^{-9}$ g	0.7 %
m_{UEC101}	53.50700 g	$3.00 \cdot 10^{-3}$ g	normal	$790 \cdot 10^{-6}$	$2.4 \cdot 10^{-6}$ g	17.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	0.043	$1.1 \cdot 10^{-6}$ g	3.4 %
$m_{aliquot1}$	2.515000 g	$300 \cdot 10^{-6}$ g	normal	0.017	$5.1 \cdot 10^{-6}$ g	78.9 %
$m_{238Uvial1}$	0.04308128 g	$5.78 \cdot 10^{-6}$ g				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
$\gamma_{Umixture}$	0.0212905 g/g	$2.3 \cdot 10^{-6}$ g/g	2.00	manual
$\gamma_{235Umixture}$	$4.09955 \cdot 10^{-3}$ g/g	$670 \cdot 10^{-9}$ g/g	2.00	manual
$\gamma_{238Umixture}$	0.0171297 g/g	$2.1 \cdot 10^{-6}$ g/g	2.00	manual
$c_{Umixture}$	$89.6607 \cdot 10^{-6}$ mol/g	$9.5 \cdot 10^{-9}$ mol/g	2.00	manual
$c_{235Umixture}$	$17.4416 \cdot 10^{-6}$ mol/g	$2.8 \cdot 10^{-9}$ mol/g	2.00	manual
$c_{238Umixture}$	$71.9583 \cdot 10^{-6}$ mol/g	$8.9 \cdot 10^{-9}$ mol/g	2.00	manual
M_U	237.455902 g/mol	$95 \cdot 10^{-6}$ g/mol	2.00	manual
$R_{233U/238U}$	0.0 mol/mol	0.0 mol/mol	2.00	manual
$R_{234U/238U}$	$2.56817 \cdot 10^{-3}$ mol/mol	$610 \cdot 10^{-9}$ mol/mol	2.00	manual
$R_{235U/238U}$	0.242385 mol/mol	$48 \cdot 10^{-6}$ mol/mol	2.00	manual
$R_{236U/238U}$	$1.05586 \cdot 10^{-3}$ mol/mol	$240 \cdot 10^{-9}$ mol/mol	2.00	manual
f_{233U}	0.0 mol/mol	0.0 mol/mol	2.00	manual
f_{234U}	$2.06112 \cdot 10^{-3}$ mol/mol	$430 \cdot 10^{-9}$ mol/mol	2.00	manual
f_{235U}	0.194529 mol/mol	$31 \cdot 10^{-6}$ mol/mol	2.00	manual
f_{236U}	$847.40 \cdot 10^{-6}$ mol/mol	$170 \cdot 10^{-9}$ mol/mol	2.00	manual
f_{238U}	0.802562 mol/mol	$31 \cdot 10^{-6}$ mol/mol	2.00	manual
w_{233U}	0.0 g/g	0.0 g/g	2.00	manual
w_{234U}	$2.03148 \cdot 10^{-3}$ g/g	$420 \cdot 10^{-9}$ g/g	2.00	manual
w_{235U}	0.192553 g/g	$31 \cdot 10^{-6}$ g/g	2.00	manual
w_{236U}	$842.36 \cdot 10^{-6}$ g/g	$170 \cdot 10^{-9}$ g/g	2.00	manual
w_{238U}	0.804573 g/g	$31 \cdot 10^{-6}$ g/g	2.00	manual
$m_{235Uvial1}$	0.0103104 g	$3.0 \cdot 10^{-6}$ g	2.00	manual
$m_{238Uvial1}$	0.043081 g	$12 \cdot 10^{-6}$ g	2.00	manual

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Author(s): R. Jakopič, J. Bauwens, R. Buják, R. Eykens, C. Hennessy, F. Kehoe, H. Kühn, S. Richter and Y. Aregbe

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Abstract
IRMM Large-Sized Dried (LSD) Spikes are widely used as a fundamental part of the fissile material control of irradiated nuclear fuel and have been provided on a regular basis to safeguards authorities and industry for more than 10 years. This report describes the preparation and certification of a new batch of LSD Spikes. IRMM-1027o is a dried nitrate material in cellulose acetate butyrate (CAB), certified for the mass of uranium and plutonium and isotope amount ratios per unit. The material was produced following ISO Guide 34:2009 .
The certified reference materials uranium metal EC NRM 101, enriched uranium metal NBL CRM-116 and plutonium metal CETAMA MP2 were used as starting materials to prepare the mother solution. This solution was dispensed by means of an automated robot system into individual units and dried down. A solution of an organic substance, cellulose acetate butyrate (CAB), was dried on the spike material as a stabilizer to retain the dried material at the bottom of the vial.
Between unit-homogeneity was quantified and stability during dispatch and storage were assessed in accordance with ISO Guide 35:2006 .
The certified values were obtained from the gravimetric preparation of the mother solution, taking into account the mass, purity and isotopic abundances of the starting materials, the mass of the mother solution, and the mass of an aliquot in each individual unit. The certified values were confirmed by isotope dilution thermal ionisation mass spectrometry (ID-TIMS) and thermal ionisation mass spectrometry (TIMS) as independent confirmation methods.
Uncertainties of the certified values were estimated in compliance with the Guide to the Expression of Uncertainty in Measurement (GUM) and include uncertainties related to possible inhomogeneity and to characterisation.
This spike CRM is applied as a calibrant to measure the uranium and plutonium amount content of dissolved spent nuclear fuel solutions using isotope dilution mass spectrometry (IDMS). Each unit contains about 50 mg of uranium with a relative mass fraction $m(^{235}U)/m(U)$ of 19.3% and 1.8 mg of plutonium with a relative mass fraction $m(^{239}Pu)/m(Pu)$ of 97.8% as dried nitrate in CAB. The whole amount of sample per unit has to be used for analysis.

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